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THESIS

COMPARISON OF FLIR TACTICAL DECISION AIDS FOR INTER-SERVICE USE

by

Daniel Machado

September 1998

Thesis Advisor:	Alfred W. Cooper
Co-Advisor:	Kenneth L. Davidson

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Within the concept of Joint Operations, which has become crucial in the modern battlefield environment, all the services must share procedures, techniques, and often the same technology. This thesis presents a comparison between the Army FLIR TDA, (ACQUIRE), and the infrared module of the Navy/Air Force TDA, WinEOTDA. Differences in the modeling of underlying physical principles, input parameters, and predicted target detection ranges are presented. Despite differences in input and treatment of environmental effects this analysis indicates similar levels of accuracy for the two codes. For two scenarios selected average predictions for three "typical" sensors fall within 20% of published observations. With further analysis and an operational evaluation it may be possible to select one Electro-Optical Tactical Decision Aid for all branches of the military.

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COMPARISON OF FLIR TACTICAL DECISION AIDS FOR INTER-SERVICE USE

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Lieutenant Colonel, Venezuelan Army

Submitted in partial fulfillment of the
requirements for the degree of

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LIST OF SYMBOLS, ACRONYMS, AND/OR ABBREVIATIONS

°F	Degrees Fahrenheit
µm	Micrometers
ΔT	Difference in Temperature
BL	Boundary Layer
DOD	Department of Defense
EOTDA	Electro-Optical Tactical Decision Aid
FLIR	Forward-Looking Infrared
ft	feet
hft	hundreds of feet
K	Kelvin
kft	thousands of feet
k(s)	knots
L	Local Time
MDT	Minimum Detectable Temperature
MRT	Minimum Resolvable Temperature
NAM	Navy Aerosol Model
nmi	nautical miles
NFOV	Narrow Field of View
TAF	Terminal Aerodome Forecast
TCM2	Target Contrast Model
TOT	Time over Target
WFOV	Wide Field of View
Z	Zulu or military universal time

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I. INTRODUCTION

A tactical decision aid (TDA) is defined by Integrated Performance Decisions, Inc. at its web page as a tool or set of tools which aid an operator in performing a task. Included in this definition are maneuvering recommendations, weapon or decoy placement recommendations, target motion analysis, and performance predictions. It should help a decision maker (Commander or whoever in charge) by assimilation and convenient presentation of data (on targets, own assets and the environment) which of themselves are useful, and by providing analysis of the tactical problem beyond what is feasible by humans in a timely fashion.

TDAs can have the form of various types of design product, including nomographs, manuals, guides, and of course, TDA programs (codes) resident on desktop computers. This thesis focuses on TDA codes for Electro-Optical applications; from now on these will be addressed as EOTDA.

An EOTDA typically consists of input and output processors and three main models: a Target Model that determines the inherent signal that emanates from scene objects; an Atmospheric Model which estimates the degradation of signal from target to sensor due to weather conditions; and a Sensor Model which determines the range at which an object can be detected or at which a weapon system can lock-on.

In this work, we will evaluate the TDA codes used by the US Navy (EOTDA) and US Army (ACQUIRE) for determining and predicting detection ranges, and the possibility to use them as standard TDAs for all services or for Joint service use.

The Army code ACQUIRE is an analytical model based on the static performance model FLIR92. It predicts target acquisition performance for systems in which the image is in the visible, near infrared, and infrared spectral bands. The detection ranges and probabilities predicted by the model represent the expected performance of a set of observers (well trained) with respect to an average target having a specified signature and size. In this thesis we will discuss the ACQUIRE version 1 model, dated May 1995.

The Navy code EOTDA is a PC based program, designed mainly as a mission-planning tool. It can be used by operational units to predict performance of electro-optical weapon systems in the infrared, visible, and laser bands. Prediction is based upon meteorological data (forecast), target characteristics, weapon system, and tactics. In this thesis we will discuss the EOTDA version 3, dated Jan 1993 and/or the open distribution version Win-EOTDA 0.7, dated 1997.

In this age of smart weapons, more sophisticated methods of weapon delivery have been developed. These methods always deal with important and natural phenomena, the changing environmental conditions. So, it is necessary to have accurate meteorological analyses and forecasts to properly plan and effectively execute tactical operations. On the other hand, it is also necessary to present this kind of data in a tactically relevant form in order for it to be easily assimilated for operational purposes. Here is where TDAs are very useful as mission-planning tools.

The first part of this work will deal with a brief discussion of the theory behind these codes, Infrared Radiation theory. The next step will be an analysis and comparison of how the theory is implemented in the codes. Finally, a comparison in performance will be made of predicted target detection range output from the two programs for equivalent operator inputs.

II. THEORY AND BACKGROUND

A. GENERALITIES

An Electro-optical Tactical Decision Aid (TDA) is a software model that predicts the performance of an air-to-ground weapon system based on environmental and tactical information. The two models, ACQUIRE and Win-EOTDA, can perform predictions in the visible, near infrared and infrared spectral bands.

The part of the spectrum that includes our area of interest is shown in Figure 2.1 that represents the portion of the Infrared (IR) spectrum characterized by atmospheric windows; that is, regions in which the atmosphere is transparent to radiation.

[Ref. 1:p.179].

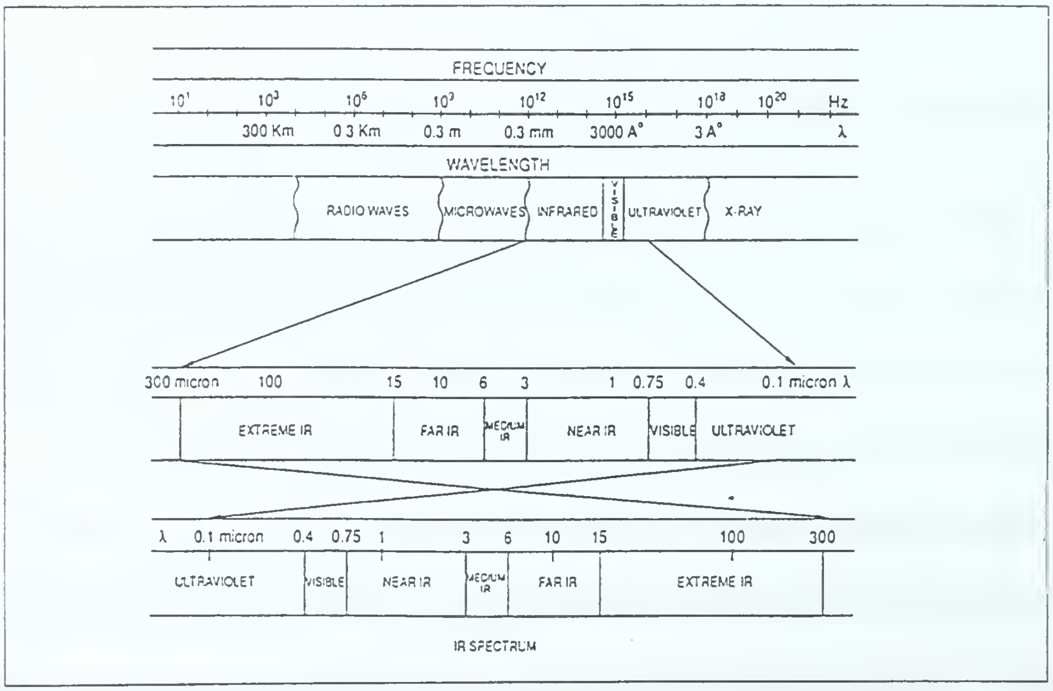

FRECUENCY
10^{1} 10^{3} 10^{6} 10^{9} 10^{12} 10^{15} 10^{18} 10^{20} Hz
300 Km 0.3 Km 0.3 m 0.3 mm 3000 A° 3 A° λ
WAVELENGTH
RADIO WAVES
MICROWAVES
INFRARED
VISIBLE
ULTRAVIOLET
X-RAY
300 micron 100 15 10 6 3 1 0.75 0.4 0.1 micron λ
EXTREME IR
FAR IR
MEDIUM IR
NEAR IR
VISIBLE
ULTRAVIOLET
λ 0.1 micron 0.4 0.75 1 3 6 10 15 100 300
ULTRAVIOLET
VISIBLE
NEAR IR
MEDIUM IR
FAR IR
EXTREME IR
IR SPECTRUM

Figure 2.1 The Electromagnetic and IR Spectra

Infrared imaging is the remote sensing and display of infrared flux variations. The variations in the displayed image intensity represent apparent temperature variations across the scene [Ref.2: p. 7]. A single scene can be represented by an isolated target and its surroundings (background). The radiation received from a target is compared with that of an equivalent area of the background. The radiation emitted and reflected from both target and background traverse the atmosphere and the aerosol particles suspended in it. The target detection is determined by the distribution of temperature over its surface in contrast with the temperature distribution of the background, allowing for the attenuating effect of the atmospheric path. The next section summarizes information related to thermal radiation theory which can be found (and more explicitly detailed) in many tutorial sources, for example "The Infrared Handbook" [Ref.3].

B. THERMAL RADIATION THEORY

Optical radiation covers a specific part of the electromagnetic spectrum as we have seen before. There are no sharp boundaries between regions; rather, they are distinguished from each other by methods of production and detection, transmission through the atmosphere, response of the human eye, etc.[Ref. 7:p.1-25].

We start a brief summary of Black Body theory by saying that all objects with temperature above absolute zero emit some kind of radiation. A black body is defined as an ideal body or surface that absorbs all radiant energy falling upon it, with no reflection or retransmission. As we will see, blackbodies have been studied by many scientists; they have stated two important emission properties of a blackbody:

a. - A blackbody is a perfect emitter of radiation at all angles and all wavelengths.

b. - The total emitted energy of a blackbody is a function only of its temperature [Ref.4:p.45].

1. Planck's Blackbody Law

Planck hypothesized that a blackbody at a given temperature emits radiation of all wavelengths. In particular, the radiant exitance at the various wavelengths integrated over a one-micron (μm) band around ν, is given by Planck's law:

$$M_{BB\ (\nu,T)} = \frac{2\pi h \nu^5}{c^3 (e^{h\nu / kT} - 1)} , \qquad 2.1$$

where :

h is Planck's constant = 6.625 x 10^{34} Ws^2,

c is the speed of light,

k is Boltzmann's constant = 1.380 x 10^{-23} J-$K^{-1,}$

ν is radiation frequency, Hz, and

T is temperature in Kelvin.

$M_{BB\ (\nu,T)}$ = Spectral Radiant Exitance, also called Radiant Emittance, is defined as the power per unit area per unit wavelength interval at a particular wavelength [Ref.8]. This equation can be simplified using defined constants and expressed in terms of wavelength, λ:

$$M_{BB(\lambda)} = \frac{C_1}{\lambda^5 (e^{C_2/\lambda T} - 1)}, \qquad 2.2$$

Where :

$C_1 = 2\pi hc^2 = 3.741 \times 10^4$ W cm^{-2} μm^{4}.

$C_2 = ch/k = 1.438 \times 10^4$ μm K, and

λ = is the wavelength, μm.

Both equations express the spectral radiant exitance/emittance of a source radiating in a vacuum. We see in Figure 2.2 the spectral radiant emittance of a blackbody at different wavelengths.

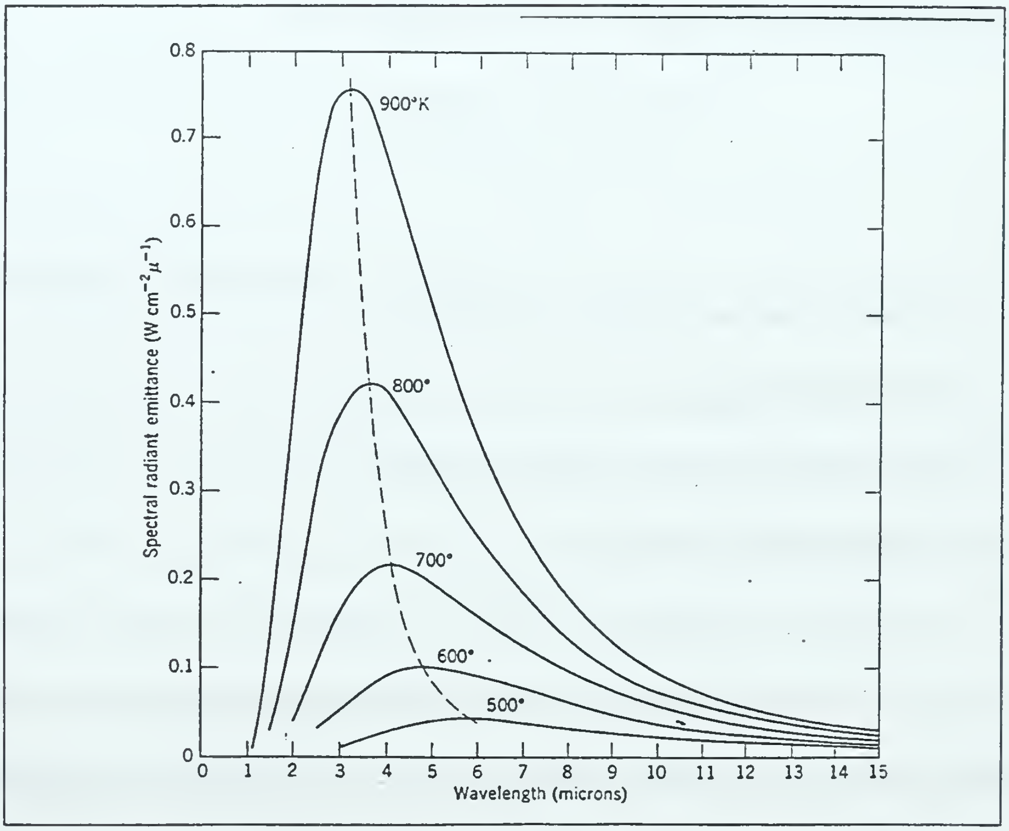


Figure 2.2 Radiant Emittance of a Blackbody [Ref.8]

When we are dealing with non-blackbodies, we have to consider an additional factor, which introduces the special characteristics of the material composition and surface condition. It is called “the emissivity constant” and represents the ratio between the emitted radiation of any given temperature radiator and the emitted radiation of a blackbody of the same temperature.

$$M_B = \varepsilon \, M_{BB} \,, \qquad 2.3$$

where :

ε = is the emissivity of the non-blackbody.

2. Stefan-Boltzmann Law

The total radiated energy from a unit area of a surface per unit time over a 2π steradian solid angle is called the total radiant exitance of that surface. The dependence of total radiant exitance on the absolute temperature of a blackbody is described by Stefan-Boltzmann’s law:

$$M_{(T)} = \sigma \, T^4 \qquad 2.4$$

where σ is the Stefan-Boltzmann constant = 5.67×10^{-12} W-cm^{-2} K^{-4}

The same relationship as before has to be considered if the object is a non-blackbody. So, radiation falling on a body is absorbed, reflected, or transmitted and because of the law of conservation of energy,

$$\alpha + \rho + \tau = 1$$

where α is the absorptance, ρ is the reflectance, and τ is the transmittance with all of them wavelength-dependent.

3. Kirchhoff's Law

Kirchhoff observed that, at given temperature, the ratio of a body's radiant exitance to its absorptance is constant, and equal to the radiant exitance of a blackbody, at the same temperature:

$$\frac{W}{\alpha} = W_0. \qquad \text{This is Kirchhoff's law.}$$

Therefore, if a body is a good absorber of radiation, its emissive capability, as expressed by W, must be good too, since the ratio is constant. That is why a good absorber is also a good emitter.

Thus,

$$\frac{\varepsilon \sigma T^4}{\alpha} = \sigma T^4 \text{ and, therefore,} \qquad 2.5$$

$\varepsilon = \alpha$, the emissivity of a body is equal to its absorptance and depends on:

* the nature of the body.

* its temperature.

* its surface finish.

* the wavelength.

Another consideration is the fact that we often work with "atmospheric windows," which means that we can subdivide our spectrum into specific sections of interest. In these cases we can estimate the "In-band Fractional Power" or in-band radiance "N" [Ref.5], using the "Universal Blackbody Curve" or the proportional radiation table, with

$$\mathrm{N} = \frac{\varepsilon \sigma T^4}{\pi} \Delta q \,, \qquad 2.6$$

Where Δq = difference of two q values for the limiting wavelengths from the proportional radiation table (See Appendix A). The proportional radiation q is a function of the wavelength and temperature. It represents the fraction of the radiant exitance emitted by a blackbody at temperature T at all wavelengths up to the specific value of wavelength, λ.

4. Lambert-Beer Law

In order to "see" the target, we have to know or detect the radiance seen by the sensor, after propagation through the atmosphere. In order to do this, we have to know how the atmosphere interacts with the optical ray on its way to the sensor. It has been stated that the transmittance is a strong function of the wavelength, which can be described by the Lambert-Beer law:

$$\tau_{(\lambda)} = e^{-\mu R} \,, \qquad 2.7$$

where,

$\tau_{(\lambda)}$ = Spectral atmospheric transmittance,

$\mu(\tau)$ = extinction coefficient,

R = Path length,

The extinction coefficient depends on the atmospheric molecular composition and aerosol concentration. It is very sensitive to the specific frequencies of the molecular vibration and rotation transitions. Of special interest for IR emission are energy transitions of the vibrational type that produce spectra in the band from 0.3 to 30 μm [Ref.1: p.190].

The infrared radiation will be attenuated as it propagates through the atmosphere by the processes of absorption and scattering. The attenuation is characterized by the total extinction coefficient,

$$\mu = \mu_a + \mu_s, \tag{2.8}$$

where,

μ = total extinction coefficient,

μ_a = extinction coefficient for total absorption,

μ_s = extinction coefficient for total scattering.

Each of these two extinction coefficients has two other components; one from the molecules of the air and the other from aerosol particles suspended in it. Scattering by aerosols and molecules has a large effect in the visible region, while absorption dominates in the infrared region of the electromagnetic spectrum. As the EO systems are designed to operate mainly between 8 and 12 μm, it is important to predict the transmittance of the atmosphere as a function of wavelength and weather conditions. These two extinction coefficients are described by the equations:

$$\mu_a = K_m + K_a \ , \qquad 2.9$$

$$\mu_s = \sigma_m + \sigma_a \ , \qquad 2.10$$

where,

K_m = molecular absorption coefficient,

K_a = aerosol absorption coefficient,

σ_m = molecular scattering coefficient,

σ_a = aerosol scattering coefficient.

Earth's atmosphere is a mixture of many gases with varying characteristics of absorption, emission, and scattering of optical radiation. Each of these gaseous quantities varies with altitude, time, and space as a function of geographical region. [Ref. 4: p.71] So, the relative values of the four coefficients will change depending upon the region where the measurement is made.

Due to the large number of parameters involved in optical transmission a range of computer models have been developed for computation of atmospheric transmittance and atmospheric path radiance for various defined meteorological scenarios. These models include LOWTRAN, MODTRAN, HITRAN and variations of those.

Gathering all these concepts and theoretical and experimental laws we can get an idea how detection scenario looks in the IR arena. Broadly speaking we have three main components: a target and its surroundings, a sensor system on a moving platform, and an atmospheric path between them.

According to Holst, the 1975 NVL and FLIR92 models are the main analytic tools for deriving system requirements and predicting performance for FLIR systems. The 1975 NVL model was developed for serial and parallel scanning thermal imaging systems that existed in the 1970s. FLIR92 is built upon the framework of the 1975 NVL model. The three–dimensional noise model and FLIR92 are in symmetrical formats. This permits a format that is easier to understand than the 1975 NVL model, although both provide similar results [Ref. 2:p. 389-391].

C. FLIR SYSTEM PERFORMANCE

The purpose of a FLIR system is to detect the arrival of IR energy, electronically process the detected energy, and display the results to the FLIR operator. There are two standard parameters for describing FLIR performance: Minimum Detectable Temperature Difference (MDTD or MDT) and Minimum Resolvable Temperature Difference (MRTD or MRT). Each of these provides a sensitivity measurement of the FLIR system.

1. MRTD

The MRTD method of FLIR system description is the most commonly used. The definition of MRTD is " the smallest temperature difference in a standard periodic test pattern for a given spatial frequency that is resolvable to an observer over an unlimited viewing time" [Ref.6:p.242]. So, it gives the ΔT between the target and ambient temperature of a standard 4 bar (7:1 aspect ratio) chart required to make the bars just resolvable as a function of the spatial frequency.

Shumaker gives a typical form for the MRTD equation. [Ref. 7: p.8-52]

$$MRT(v) = \frac{2 * SNRT * NET * \rho_x^{1/2}}{MTF(v)} \left[\frac{v^2 * \Delta_x * \Delta_y}{L} \right]^{1/2} \left[t_e * F_r * N_{os} * N_{ss} \right]^{-1/2}, \qquad 2.11$$

where,

SNRT = signal to noise ratio threshold
NET = Noise Equivalent Temperature
MTF = Modulation Transfer Function
N_{os} = Overscan ratio
N_{ss} = Serial scan ratio
L = Length-to- width ratio of the bar
v = Spatial frequency
t_e = eye integration time in seconds
F_r = Frame rate
ρ_x = Noise filter factor
Δ_x = in-scan detector subtense
Δ_y = cross-scan detector subtense

For calculations purposes it is convenient to express MRTD as a function of spatial frequency f in a parametric form.

$$\mathrm{MRTD} = \mathrm{SL} + \mathrm{SC}*2*\frac{f}{\varepsilon^{1/2}}\,\exp^{\left(\frac{1}{2}\pi ER^{2}f^{2}\right)}, \qquad 2.12$$

where SL is the sensitivity limit, SC is the sensitivity contrast and ER is the Equivalent Resolution. All three constants are derived for any given FLIR by fitting the equation 2.12 to the measured or calculated MRTD of the system for a 4 bar target pattern with aspect ratio equal to 7. FLIR constants are not generally available for specific military FLIR instruments but can be deduced from suitable generic models. Since MRTD is a function of spatial frequency, the maximum range for classification or recognition is the range at which the ship/background ΔT matches MRTD at the spatial frequency given by the appropriate criterion (e.g., the Johnson Criterion).

2. MDTD

The MDTD definition of a FLIR system is similar to the MRTD, but the target is represented as a large square and MDTD is not as dependent on the eye parameters. The definition of MDTD is the minimum detectable temperature difference between a large square target and its background that just makes the square target detectable. Shumaker also provides a typical form for MDTD [Ref. 7: p.8-55].

The calculations of MDTD for a generic FLIR system can be described by a curve fit equation as shown in equation 2.13,

$$MDTD = SL + \left(\frac{SC}{TAS^2} * \left(TAS^2 + ER^2\right)^{1/2} \right) \qquad 2.13$$

where SL, SC and ER are empirical FLIR constants as before. TAS represents the target angular subtense in mRad, which equals $10^6 \frac{A_T}{R^2}$. A_T is the projected area of the target, and R is the range.

The effective temperature difference, ΔT, is the temperature difference required of two blackbodies to produce the actual in-band average radiance difference between a target and its background. Shumaker provides a detailed discussion of all the factors that must be considered in determining the nature and magnitude of thermal signatures, and relates them to a ΔT that can be used to characterize targets for analysis [Ref.7:p.2-19].

3. Johnson Criteria

In 1958, Johnson conducted an experiment using eight military vehicles and one observer to develop a relationship between spatial frequency and a target. During the experiment, Johnson placed tri-bar patterns next to military targets as he varied conditions. He noted what tri-bar frequency could just be resolved when a given visual discrimination task was accomplished. Then, he related the visual discrimination levels to the Air Force tri-bar target frequencies using the minimum dimension of the target as a reference. From this experiment, and some improvements to relate the results to FLIR systems the Johnson Criteria was established. The table 2.1 contains the two dimensional cycle criteria for a 50% probability of task discrimination that are in current use.

Discrimination Level	**Definition**	**2-D Cycles**
DETECTION	An object is present (Object vs. Noise)	0.75
CLASSIFICATION	Distinguish targets from similar sized non-targets	1.5
RECOGNITION	The class to which the object belongs (tank,Truck, Destroyer)	3.0
IDENTIFICATION	Determines the specific military designation (T72 tank,DD963, CVN69)	6.0

Table 2.1 Two-dimensional Johnson Cycle Criteria.

In order to establish the bar-chart equivalent of a specific discrimination task, selecting the proper target size is critical in obtaining meaningful results. In Johnson's original work, he chose the minimum target dimension as the target's "***characteristic dimension.***" Lawson and Moser found that using the average target dimension (square root of its area) as the "***characteristic dimension***" led to consistent predictions for targets regardless of aspect, while use of the minimum dimension led to erroneous conclusions. The area of the target that is of concern to the FLIR analyst is that projected area normal to the line-of-sight from the sensor to the target. This area is dependent on the target dimensions, the observing aspect, and any obscuration of the target.

Shumaker provides detailed descriptions and physical dimensions for a variety of military targets [Ref.7:p.2-8/2-14].

III. COMPETING MODELS

A. TACTICAL DECISION AIDS

The Tactical Decision Aids (TDA) are special tools designed for assisting a decision maker by assimilation and convenient presentation of data and analysis of tactical problems beyond what is feasible by humans in timely fashion. Since the advances of the technology go on and on, the weapon systems have reached a high level of development that sometimes makes them very difficult to use in the operational environment. This is one of the main reasons why we have TDAs, [Ref.9: p.1-1].

According to Holst, Electro-optical imaging system analysis is a mathematical construct that provides an optimum design through appropriate tradeoff analyses. A comprehensive model must include the target, the background, the properties of the intervening atmosphere, the optical system, detector, electronics, and the human interpretation of the displayed information. While any of the components can be studied in detail separately, the whole Electro-optical imaging system cannot.[Ref. 2 : p.12-13]

An EOTDA typically consists of input and output processors and three main models: a Target Model that determines the inherent signal that emanates from scene objects, an Atmospheric Model which estimates the degradation of signal from target to sensor due to weather conditions, and a Sensor Model which determines the range at which an object can be detected or at which a weapon system can lock-on. This thesis describes each one of these two codes (under study) based upon these three main or fundamental parts plus the way that each one presents the outputs. See Figure 3.1 on page 58 for a Functional Diagram of a general TDA.

B. ACQUIRE MODEL

ACQUIRE is an analytical model that predicts target detection and discrimination range performance for systems that image in the visible, near infrared and infrared spectral bands. Broadly speaking it is a FORTRAN program designed to run on IBM-compatible PCs and Unix workstations. Also, it is intended for experienced system analysts who are knowledgeable of IR technology and the basic methodology applied in the model.

This thesis uses ACQUIRE version 1 dated May 1995. The model was developed by the U.S. Army Night Vision and Electronic Sensors Directorate, at Fort Belvoir, Virginia. As for other Electro-optic system range performance models, three main components are built in:

1. The Target Model

The program calculates the probability-range relationship based on input target characteristics (length, height, and target-background temperature difference), atmospheric conditions, MRTD curves, and a 2D formulation of the Johnson's Cycle Criteria methodology. Basically, the target is represented by a temperature difference against background. The target signature is either the target contrast (visible or near IR imager) or "delta T" the zero-range temperature difference between the target and its background (thermal imager).

The model includes range prediction methodologies for both target discrimination and target spot detection. For a target imbedded in a nonuniform or cluttered background, discrimination of characteristics that separate the target from the background is required in order to perform detection. For a target against a uniform background, detection may occur when the signal-to-noise ratio (SNR) on the display element representing the target exceeds the SNR of the background.

Target discrimination is usually divided into three levels: detection, recognition, and identification. Detection can be defined as the determination that a target of potential military interest is present within the sensor field-of-view. Recognition would be the discrimination between specific objects within a class of similar objects (truck, tank, APC, etc). Identification is defined as the discrimination between specific targets (T-72, M1, etc) [Ref. 10: p.1].

Due to advances in technology and improvements to FLIR systems, Johnson's Criteria have had to be updated. A series of perception tests conducted by the U.S. Army CECOM Center for Night Vision and Electro-optics Visionics Division demonstrated that both horizontal and vertical resolution are equally important to determine the ability of test subjects to perform visual discrimination tasks. This correction was made to the Johnson Criteria, which generated a new level of target discrimination, **classification** that can be defined as discrimination between general classes of vehicles [Ref.10: p.13].

ACQUIRE User's Guide defines the probability of target discrimination as a function of the number of equivalent cycles resolved on the target by the sensor. For a given target at specific range and apparent signature, the number of cycles resolved is determined by either Minimum Resolvable Temperature Difference (MRTD or MRT) or Minimum Resolvable Contrast (MRC), and is given by:

$$\mathrm{n} = \frac{C_D}{R} * f_R \qquad 3.1$$

where,

C_D is the Characteristic Size of the target (Critical Dimension) in meters, R is the range to the target in kilometers and f_R is the frequency in cycles per miliradian resolved by the sensor. ACQUIRE uses an empirical curve fit to the Target Transfer Probability Function (TTPF) that is given by:

$$\mathrm{P} = \frac{(n/n_{50})^E}{1 + (n/n_{50})^E} \qquad 3.2$$

where $E = 2.7 + 0.7\,(n/n_{50})$.

(n/n_{50}) is the number of cycles required to be resolved in order to achieve a 50% probability of target discrimination (detection, classification, recognition, or identification)[Ref.9].

In the case when a target is against a uniform background, the detection range is calculated using either Minimum Detectable Temperature Difference (MDTD) or Minimum Detectable Contrast (MDC) and threshold signal-to-noise ratio.

ACQUIRE includes 23 standard targets (small land targets) to select from the target_lookup table, if the target is not included, a target data group must be created. This data group is used to specify the size, as its critical dimension, and signature of the target.

2. The Atmospheric Model

To reach the IR detector, the radiant flux from the target has to pass through the atmosphere. The earth's atmosphere is filled with absorbing agents, components of the atmosphere, which extract energy from the supply of radiation (attenuation). Also, the small particles suspended in the atmosphere cause scattering and emission of IR radiation in all directions.

The most significant absorbers in the atmosphere are water, carbon dioxide, and ozone. On the other hand, scattering is produced by molecules of the air and aerosol particles suspended on it. The ratio of the intensity of usable radiation passing through a body of air and entering an optical system to the intensity originating from the target is known as the ***atmospheric transmittance*** [Ref. 7 :p.3-1].

ACQUIRE has two options for modeling atmospheric transmittance. The first option is using Beer's Law, in which the atmospheric transmittance (τ_a) is given by:

$$\tau_a = e^{-\mu R} \qquad 3.3$$

where μ is the attenuation (extinction) coefficient (km^{-1}) and **R** is the range (km). The extinction coefficient includes the molecular scattering coefficient, the molecular absorption coefficient, the aerosol absorption coefficient, and the aerosol scattering coefficient. For a finite bandwidth, Beer's Law with a single constant extinction coefficient frequently does not adequately represent the extintion.

The second option, recommended in the ACQUIRE Users Guide, is to specify atmospheric transmittance as a function of range. Several models exist for computing the transmittance; the most commonly used is LOWTRAN. Currently, Lowtran is being retired in favor of MODTRAN. This method requires the standard meteorology data set.

The effects of smokes and obscurants are included by specifying a mass extinction coefficient and a concentration length. ACQUIRE, then modifies (attenuates) the target signature due the atmospheric transmittance and smoke transmittance.

3. The Sensor Model

The sensor model in this code is selected according to its specific performance parameters. They are selected as MRT, MDT, MRC, or MDC from a look-up table. Each sensor has a specific character string ID which is required as input data. The sensor IDs must match with sensor performance curve data that is stored in a special data file. ACQUIRE also lets users define specific sensors when they are not included in the lookup table. In this case, the horizontal field of view is required in order to calculate search performance; it must match the input MRT or MRC data points.

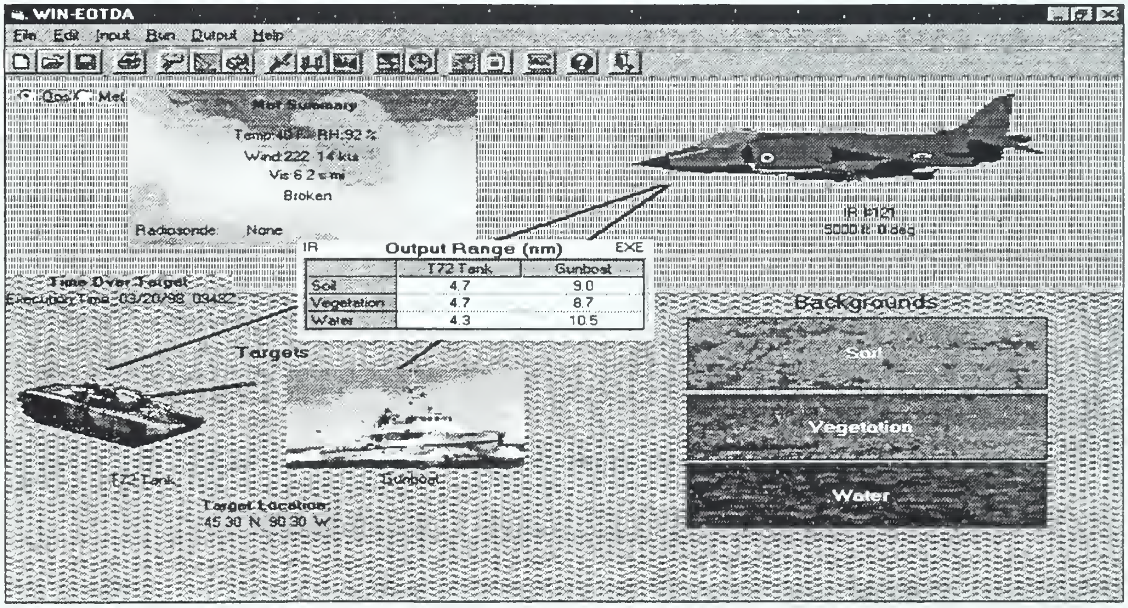
C. WIN-EOTDA

The Naval Research Laboratory, in Monterey, CA, developed Win-EOTDA version 1.0. This product was derived from the Mark III Electro-Optical Tactical Decision

Aid (EOTDA), which was originally developed by the USAF Phillips Laboratory. This thesis uses Win-EOTDA version 0.7 dated June 1997, which is a special version just for experimental purposes [WinEOTDA Program Help].

Windows Electro-Optical Tactical Decision Aid (WinEOTDA) is a computer model that predicts the performance of Electro-optical systems, based on environmental and tactical information. The model consists of three microcomputer-based programs supporting infrared (8-12 μm), visible (0.4-0.9 μm), and laser (1.06 μm) systems. Each program is comprised of three sub-models: an atmospheric transmission model, a target contrast model, and a sensor performance model.

WinEOTDA has been designed to simplify the process of predicting performance of Electro-optical weapon systems and night vision goggles (NVG). The input and the outputs are presented on a single easy to read form, shown as Figure 3.2. It has a main



Temp:40 F RH:92 %
Wind:222 14 kts
Vis 6.2 s mi
Broken

Radiosonde: None

Time Over Target
Execution Time 03/20/98 0348Z

IR Output Range (nm) EXE

	T72 Tank	Gunboat
Soil	4.7	9.0
Vegetation	4.7	8.7
Water	4.3	10.5

IR 121
5000 ft 0 deg

Target Location:
45 30 N 90 30 W

Figure 3.2 WinEOTDA Main Screen

screen that contains both input and output in a graphical representation, both of them available at a single click of the mouse.

Input data can be changed from the main menu, the toolbar, and by clicking on hot spots on the main screen. Data entry forms will appear and guide users through the input process. Output can be found on the main screen and on a separate form that appears when you select "Output Form" from the main menu or toolbar. Users will navigate among the various screens in the model by using both drop down menus and navigation buttons, just like any other Windows application.

The WinEOTDA main screen leads to multiple forms (and sub-models) that allow users to access a user-friendly environmental tool for performing range predictions in a variety of scenarios.

1. The Target Model

In the target model, the program calculates the difference in radiance between target and background over the wavelength band from 8 to 12 μm. This radiance difference is then converted to a temperature difference. The thermal model converts the physical temperature of the target and background to an equivalent blackbody temperature.

The thermal model is based on the Target Contrast Model #2 (TCM2), which treats the target as a three-dimensional network of nodes that exchange heat with one another and with the environment, providing a detailed thermal signature. The number of nodes per target varies from 17 nodes for the POL tank to 68 nodes for the Apache Helicopter (AH-64).

The principal phenomena interacting to produce the thermal scene are radiative heating and cooling; mass and heat transfer effects of evaporation, condensation, sublimation, and precipitation; the thermal properties of the target and background; and the thermal transfer by wind [Ref. 11:p. A-1].

The TCM2 computes a mean target temperature and it also identifies the hottest and coldest of the visible nodes. It then identifies which of these has the greater contrast with the background. This identified node gives the target contrast temperature difference.

The WinEOTDA includes 18 standard military (tanks, frigate, gunboat, helicopter, power plants, etc) targets to select from, as well as eight classes of generic targets, which the user can specify. Each target is associated with up to eight types of backgrounds. The backgrounds available are vegetation, soil, snow, water, concrete, asphalt, swamp, and rocky field. Each one of these backgrounds is further described by moisture, coverage, depth (for water background), and density of the surface type. The WinEOTDA is usually used with multiple background instances (up to three) for each run. The program serves to use the first entered background as the primary background, which is used to compute reflected ground radiation. Each entered background is not considered independently. It is important, therefore, to enter the most representative background first.

2. The Atmospheric Model

The atmospheric model evaluates the attenuation of the signal by atmospheric constituents between target and sensor. The attenuation consists of four components: molecular, aerosol, precipitation, and battlefield-induced contaminants.

Molecular attenuation is due primarily to absorption by water vapor and is related to air temperature and moisture. It effects directly the Mid IR and Far IR bands as is shown in the following Table: [Ref. 13 :p.7-3].

WAVELENGTH REGION	ATTENUATION COEFICIENTS
Visible (0.4 – 0.7 μm)	Aerosol scattering – Molecular scattering
Near IR (0.7 – 2.0 μm)	Aerosol scattering – (Molecular absorption only for specific wavelength)
Mid IR (3.0 – 5.0 μm)	Molecular absorption (water vapor) – Aerosol scattering
Far IR (8.0 – 12 μm)	Molecular absorption(water vapor) – Aerosol scattering

Table 3.1 Importance of attenuation coefficients according to wavelength.

The combined transmittance resulting from the four types of attenuators is accurately evaluated by the model for a range of four kilometers. Transmittance at other ranges is estimated by assuming the exponential extinction law (Beer's law).

The WinEOTDA model contains 17 different types of aerosols from two basic models- LOWTRAN versions 5,6, and 7 use nine aerosol models and eight more from the Navy Aerosol size distribution model (NAM). The following Table shows the nine aerosols models contained in WinEOTDA [Ref.10: p.127].

Most of the aerosol model is accessed by using the entering aerosol model data. The rural model describes the boundary-layer background aerosol found in continental air masses (microscopic soil particles and manmade processes). The urban model describes

RURAL
URBAN
MARITIME
TROPOSPHERIC
DESERT
NAVY MARITIME
ADVECTIVE FOG
RADIATIVE FOG
CAMOUFLAGE SMOKES

Table 3.2 Aerosol Models

the concentration of particles produced in urban and industrial complexes. The tropospheric model characterizes aerosols found in very clean air masses and in the free atmosphere. The desert aerosol model characterizes aerosols found in the boundary layer of desert, arid, or semi arid climatic regions.

The Navy Maritime model describes the aerosol found in oceanic environments. The main difference from the other maritime model is its wind speed dependence. There is a sub menu with nine options that depend on air mass history and the average wind speed over the target area during the 24 hours previous to the aerosol model forecast time.

3. The Sensor Model

The sensor model describes the performance of the sensor in terms of the minimum resolvable or minimum detectable temperature difference as a function of spatial frequency. A user defined FLIR model can be constructed using the physical parameters of the system: overall field of view FOV, instantaneous field of view IFOV along and across scan, detector sensitivity, NET, system modulation transfer function

MTF, etc, from which MRT and MDT are deduced as function of spatial frequency (cycles/mrad).

The range performance model then determines the range at which the target contrast temperature differences modified by atmospheric transmission equals the sensor MRT or MDT. The relation between target spectral frequency (for given task of detection, recognition, etc) is defined by target size and the Johnson criterion.

The sensor performance model determines the range at which the actual contrast (temperature) signal received by the sensor equals the threshold signal for detection or lock-on. Normally, the signal decreases as the target-to-sensor range increases. The threshold signal is determined by the target's apparent size (angular subtense) as viewed from the sensor. The angular subtense is equal to the ***critical dimension*** of the target divided by range to sensor. The smaller the angular subtense, the larger the threshold value of the signal.

WinEOTDA supports three sensor types (IR, TV, or Laser). This thesis only treats IR sensors. A number of sensor data files are supplied with the program. For some of the supported sensors, system parameters and/or predicted ranges are classified when associated with the sensor name. Each sensor has a unique three-digit number associated with it. Sensor IDs are divided into two categories: standard IDs reserved for sensors supplied with the program and additional IDs for user-defined sensors. The list of software-supplied sensors and IDs is in a confidential appendix of the User's Manual. Neither the list nor the confidential appendix was available for the author of this thesis because of the classification level. This thesis utilized the generic sensor model gen1 and gen2 included in WinEOTDA and one user-defined model NACIT9.

D. SCENARIO

Since EOTDA assess the performance of air-to-ground weapon systems and ACQUIRE does the same task for small land targets, particular scenario conditions were selected for achieving and setting the comparison between these two codes. The scenario will be described according to the main sections reviewed previously.

A land target represented by a Soviet T-72 tank and a Gunboat as an air-to-sea target were selected based on the following criteria:

- Target related with TDA Code designed for.
- Target in a lookup table for both TDA codes.
- Target data availability in the references.

Operational sensor performance data were not available for use in WinEOTDA and ACQUIRE due to classification issues. Performance was estimated based on published physical descriptions of the AN/AAS-36 IRDS system. A general description of this sensor can be found in the thesis by Kreitz [Ref.11:p. 17-21]. The NACIT9 MRT model was generated using these data. The two generic models gen1 and gen2 were also used.

The atmospheric data were selected according to the typical operational scenario for each target selected. Therefore, a desert atmospheric data set for a T-72 tank target obtained from Strike Warfare Weapons School at Fallon Naval Air Station, Nevada [Ref.16] was used. Special open maritime atmospheric conditions for a Gunboat target were selected from the database of the PREOS92 experiment at Monterey Bay, performed by Naval Command, Control and Ocean Surveillance Center (NCCOSC), Research, Development, Test and Evaluation Division (NRaD) and Naval Postgraduate School (NPS) [Ref.13].

The following Table summarizes the data used as input for these targets in the ACQUIRE and WinEOTDA codes. The selection of ACQUIRE with target T-72 and WinEOTDA with target Gunboat is just an example. Each target was exposed to each code with similar parameters and under similar conditions.

DESCRIPTION	ACQUIRE: T-72	WinEOTDA: GUNBOAT
TYPE OF TARGET	LAND TARGET	AIR-TO-SEA TARGET
LOCATION	39° 14'(N) – 118° 14' (W)	36° 47' (N) - 122° 18' (W)
DIMENSION (mts)	**H:**2.16 **L:**9.33 **W:**3.35 **F:**64	**H:**8.8 **L:**41.5 **W:**9.75 **F:**60
AEROSOL	DESERT MODEL	NAVY MARITIME MODEL
SENSOR SYSTEM	AN/AAS-36 (IR)	AN/AAS-36 (IR)
TRANSMITTANCE	Calculated by Lowtran 6	Not required
TEMP(Min/Max/Min)	29/47/29 F	42/55/46 F

Table 3.3 Summary of data input for both codes: ACQUIRE and WinEOTDA
AN/AAS-36 FLIR represented by NACIT9 model

IV. DATA COMPUTATIONS AND RESULTS

A. GENERAL

ACQUIRE and WinEOTDA have their particular ways to handle data inputs, computing or calculating algorithms and the output data. This work is not intended to describe in detail the way that each code does this; it would be better to have a Technical Manual on hand for this purpose. Instead of this, the main modules of each code are presented with the data processing used to get the predicted target detection range for each for equivalent operator inputs. It is necessary to point out that both codes can perform range prediction in three well-defined bands; however this work just deals with the infrared band (8 to 12 μm).

According to Holst, performance of an optical system is optimized by performing a series of tradeoff analyses as a function of a variety of variables. As we saw previously, typical variables include field of view, atmospheric transmittance, target size, target intensity, and stabilization. Each tradeoff provides a different view of overall optimization [Ref. 2:p 441]. These tradeoffs will be pointed out in this section.

B. ACQUIRE INPUTS

The Army code ACQUIRE requires a data input file with the target, sensor and scenario parameters, which must be created before running the code. This data file must be an ASCII text file with a specified format (See Appendix B). As was pointed out in chapter two, the target can be defined using a target_lookup table or a user defined data group. The two methods were used in this work.

The target_lookup entry format used was:

```
>target_lookup
   target_id            T72    ---
   aspect               F      F_or_S
   signature            1.25   degrees_C_or_contrast
```

The **target_id** selects a T72 target from the lookup table. There are 23 small land targets in this table; also, there is a default value for a T62 target. The **aspect** represents the position of the selected target; it is related to the critical dimension directly. For the Front (F) **aspect** the critical dimension value is 2.55 meters and for the S aspect the critical dimension is 3.60 meters; these values are set in the database for each target. The code was run twice, once in each aspect to discriminate the difference in the performance. The results are included in the Appendix B. The **signature** is the difference in temperature between the target and the surrounding background. It was set as the default value for a thermal imaging system (1.25 degrees centigrade).

The other selected target was a Gunboat. In this case it was necessary to define the target characteristics because it is not represented in the internal lookup table. The format used was:

```
>target
   characteristic_size        10.12  meters
   signature                  4.6    degrees _C
```

The Gunboat is then represented by these two parameters. The **characteristic_size** represents the critical dimension of the target as defined previously. It was computed for both **aspects** Front and Side using the following equation from Shumaker [Ref.7 :p.2-15]:

$$A_T = lw\sin\theta\cos\phi + hw\cos\theta\cos\phi + hl\cos\theta\sin\phi \qquad 4.1$$

where,

$$\left.\begin{array}{ll} l & \textbf{is the target length} \\ w & \textbf{is the target width} \\ h & \textbf{is the unobscured target height} \\ \phi & \textbf{is the azimuth angle} \\ \theta & \textbf{is the elevation angle} \end{array}\right\} \textbf{of an equivalent Parallelepiped}$$

The following Table shows the parameter values of the Gunboat target based on the dimensions of the Research Vessel POINT SUR (R/V POINT SUR) which was used as a platform for the PREOS experiment in 1992. The Table also includes the critical dimension values computed by Equation 4.1.

Ship length l	41.5 meters
Ship width w	9.75 meters
Ship height h	8.80 meters
Elevation angle θ	2.80° $\sin^{-1}$(altitude / range)
Azimuth Angle Side Aspect ϕ Azimuth Angle Front Aspect ϕ	0° 90°
Projected Area A_T Side Aspect Projected Area A_T Front Aspect	384.16 m^2 102.41 m^2
Critical Dimension Side Aspect **Critical Dimension Front Aspect**	**19.60 meters** **10.12 meters**

Table 4.1 Critical Dimension of Gunboat target.

The **signature** parameter is the temperature difference between the target and its surrounding background; it was set to 4.6 degrees as the average temperature of the ship and the background during the selected day on August 4,1992. [Ref. 12:p.57-59]

The environmental effects are considered in ACQUIRE by modeling the atmospheric transmittance and the effects of smokes and obscurants. The ACQUIRE User's Guide suggests getting the atmospheric transmittance as a function of Range. Using LOWTRAN 6, an atmospheric propagation model, a set of values was obtained relating to the specific environment where those targets were supposed to operate; a desert environment and a maritime environment. Table 4.7 and 4.8 (pag.59-60) shows the parameters used as input in LOWTRAN 6. This is the only way in which ACQUIRE introduces meteorological and regional data into calculations. The format used was:

```
>band-averaged_atmosphere
  #_points: 20          Km              transmittance
                     0.000e+00          1.000e+00
```

The transmittance values are included as part of the written program for each target, and they are shown in Appendix B. Smokes and obscurants were not considered.

Another main section in the ACQUIRE input program is the sensor. It is considered as the vital part of the program. For this thesis several programs were written and run using the generic sensors (**gen1, gen2**) included with the ACQUIRE model. Also, a sensor data file was developed by the author from the available data of the AN/AAS-36 and theoretical values. The required input data defining a sensor are the MRTD and MDTD values as functions of spatial frequency, expressed in terms of empirical constants equivalent to SL, SC, and ER of equation 2.12. An appropriate set of constants was obtained by inserting the available physical parameters of the AN/AAS-36 FLIR in equation 2.11 with theoretical estimates for the terms not directly available. The corresponding set of FLIR parameters SL, SC, and ER was determined by matching equation 2.12 to equation 2.11 empirically for the useful range of spatial frequency. The optimal values of the parameters were determined iteratively using an Excel spread sheet to match the outputs of equation 2.12 to equation 2.11. Table 4.2 shows the set of values of MRTD as a function of spatial frequency, which was developed to be used as sensor inputs for each code. The estimated MRTD curve and MDTD curve for calculating range predictions were derived from Shumaker's example 8-13 and 8-16 [Ref. 7] for a generic FLIR system in WFOV. The detector angular subtense Δx and Δy were chosen as 0.45 mRad to represent a modeled FLIR system in WFOV. The Noise Equivalent Temperature Difference (NET) was chosen as 0.140 K, between 0.1K (Shumaker example) and 0.250K (Moser's reference). Figure 4.1 is the Excel data sheet including the graph of MRT curves on page 61.

	From Shumaker		Result
	0.25mRad	1mRad	0.45mRad
MRT=	0.010018	0.057341	0.017026
	0.012722	0.120642	0.024775
	0.015714	0.268442	0.034768
	0.019114	0.675595	0.048469
	0.023063	1.978021	0.068144
	0.027737	6.835714	0.097468
	0.033359	28.12041	0.142616
	0.040214	138.4451	0.214273
	0.054719	2599.65	0.436981
	0.133215	56697152	4.230673
	0.255343	2.07E+11	25.26968

Table 4.2 MRTD as function of spatial frequency for "generic" FLIR system

The sensor data file contains the data (MRT and MDT) as a function of the spatial frequency for gen1 and gen2 from the ACQUIRE database (included with the code) to be used for computing the prediction ranges. The sensor file is enclosed as a part of Appendix B. The format used was:

```
>sensor_lookup
        data_file_name      sensor.dat     ---
        sensor_id           gen1           ---
        performance_mode    MRT            MRT_MDT_MRC_or_MDC
```

Using this format, the code was run three times, first one with the data from gen1 and second with the data from gen2. The results show slight differences. The third run was with the prototype sensor data (calculated from AN/AA-36 and theoretical parameters) which was included in the same sensor data file under the name "NACIT9". These runs used the same format as above, but with the sensor_id changed from gen1 to gen2 and NACIT9.

The program files with all needed parameters were arbitrarily designated as NACIT1, NACIT11, NACIT2, NACIT21, NACIT3, and NACIT31. All of them are included in the Appendix B. ACQUIRE generates an output file with the same name as the input file plus an extension.

C. ACQUIRE OUTPUTS

From the input files reviewed previously, ACQUIRE generates an output file for each one. Each output file has an extension – r1 or r2 – The r1 file is used to verify the performance with respect to a specific probability requirement. The r2 file lists in tabular form the discrimination probability given target range, which is the way that ACQUIRE calculates performance. Six output files were obtained after the ACQUIRE computations, and these are included in the Appendix B.

The NACIT1.r1 and the similar files are basically divided into three sections. The first section is a summary of the input and default values used by ACQUIRE. The second one is a detailed examination of the intermediate result files and is presented as text messages. Figure 4.2 shows an example of this section, for the Gunboat target at Side aspect.

```
MESSAGES

    2D MRTD from lookup table


                   cyles/mrad       MRTD
                   2.970e-001     1.020e-002
                   4.300e-001     1.460e-002
                   5.990e-001     2.100e-002
                   8.200e-001     3.020e-002
                   1.091e+000     4.340e-002
                   1.390e+000     6.230e-002
                   1.692e+000     8.960e-002
                   1.987e+000     1.288e-001
                   2.265e+000     1.851e-001
                   2.522e+000     2.660e-001
                   2.754e+000     3.823e-001
                   2.959e+000     5.494e-001
                   3.148e+000     7.896e-001
                   3.300e+000     1.135e+000
                   3.440e+000     1.631e+000
                   3.567e+000     2.344e+000
                   3.649e+000     3.369e+000
                   3.723e+000     4.841e+000
                   3.778e+000     6.958e+000
                   3.834e+000     1.000e+001

        Sky-to-ground ratio defaulted to 1 for thermal systems.
        Last range for input atmospheric transmittance data is less
        than maximum range.
        Spline fit returned a negative atmospheric transmittance; add
        more points to input transmittance data array.
        Loadline does not intersect MRTD/MRC above range 15 km, extend
        curve to lower frequencies and temperatures.

SENSOR
        gen1 from sensor.dat

TARGET
        characteristic dimension: 19.6 meters
        inherent signature: 4.6 degrees C
```

Figure 4.2 ACQUIRE typical output (Messages)

The third section is the tabulated result of the run, called "Observer Ensemble Performance Range Given Probability...". The probabilities are given in five- percent steps (5%) from 0.95 percent down to 0.05 percent (5%). The following Figure shows a typical output file that is generated from ACQUIRE,

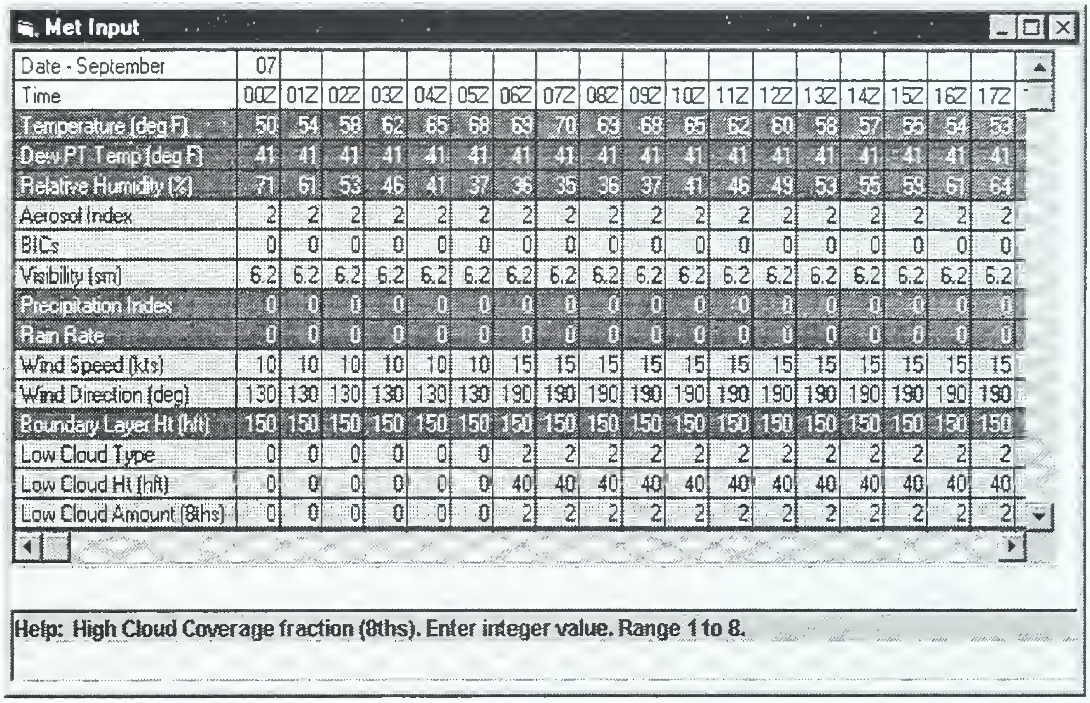
```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                 WFOV          NFOV          NFOV          NFOV          NFOV
    prob       N50=0.75      N50=0.75      N50=1.50      N50=3.00      N50=6.00
   ------     ----------    ----------    ----------    ----------    ----------
    0.95        9.74 km      12.47 km      10.87 km       8.81 km       6.19 km
    0.90       10.21          0.00         11.24          9.33          6.78
    0.85       10.48          0.00         11.49          9.65          7.18
    0.80       10.70          0.00         11.69          9.90          7.50
    0.75       10.89          0.00         11.86         10.12          7.79
    0.70       11.06          0.00         12.00         10.30          8.02
    0.65       11.20          0.00         12.13         10.46          8.25
    0.60       11.34          0.00         12.26         10.62          8.47
    0.55       11.48          0.00         12.39         10.77          8.68
    0.50       11.62          0.00         12.52         10.93          8.87
    0.45       11.76          0.00          0.00         11.08          9.08
    0.40       11.90          0.00          0.00         11.22          9.30
    0.35       12.05          0.00          0.00         11.38          9.51
    0.30       12.20          0.00          0.00         11.56          9.73
    0.25       12.38          0.00          0.00         11.76          9.98
    0.20       12.59          0.00          0.00         11.97         10.27
    0.15        0.00          0.00          0.00         12.23         10.57
    0.10        0.00          0.00          0.00         12.59         11.01
    0.05        0.00          0.00          0.00          0.00         11.65
```

Figure 4.3 ACQUIRE typical output. Gunboat at Side aspect (range performance). N50 is a Johnson cycle criterion that corresponds to a 50% probability of target task (detection, recognition, classification, identification)

D. WINEOTDA INPUTS

WinEotda requires two kinds of input data: Meteorological and Site (Met) information, and Operations and Intelligence (Ops) data. The Met data includes the location, the surface weather forecast, and the thickness of the boundary layer. The data are entered using the Met form from the main screen (left corner). The Ops data includes the electro-optical sensor_ID number, sensor height, viewing direction, targets, and backgrounds. The data are entered using the Ops form from the remaining three corners of the main screen.

The following Figure shows the WinEOTDA Met data form. It will show up by using the **input** drop down menu button and selecting **Meteorological Inputs.** A detailed description of each parameter is enclosed in Appendix C. In order to differentiate the two scenarios in this work, a set of meteorological data was used for each one based on the specific weather conditions of the previously referenced open field experiments at NAS Fallon, Nevada and off the coast of Monterey, California.



Date - September	07																	
Time	00Z	01Z	02Z	03Z	04Z	05Z	06Z	07Z	08Z	09Z	10Z	11Z	12Z	13Z	14Z	15Z	16Z	17Z
Temperature (deg F)	50	54	58	62	65	68	69	70	69	68	65	62	60	58	57	55	54	53
Dew PT Temp (deg F)	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Relative Humidity (%)	71	61	53	46	41	37	36	35	36	37	41	46	49	53	55	58	61	64
Aerosol Index	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
BICs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Visibility (sm)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Precipitation Index	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rain Rate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Speed (kts)	10	10	10	10	10	10	15	15	15	15	15	15	15	15	15	15	15	15
Wind Direction (deg)	130	130	130	130	130	130	190	190	190	190	190	190	190	190	190	190	190	190
Boundary Layer Ht (hft)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Low Cloud Type	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2
Low Cloud Ht (hft)	0	0	0	0	0	0	40	40	40	40	40	40	40	40	40	40	40	40
Low Cloud Amount (8ths)	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2

Help: High Cloud Coverage fraction (8ths). Enter integer value. Range 1 to 8.

Figure 4.4 Met Data input form for WinEOTDA (Sample)

The available/required entries for the Met-input form can be selected from the three categories: Terminal Aerodrome Forecast (TAF), non-TAF code surface parameters, and radiosonde data. Since this is a laboratory work based on recorded data, the non-TAF surface parameters were used.

The following Table shows the parameter set used for each one of the target scenarios. The Met data didn't change when different sensors were implemented.

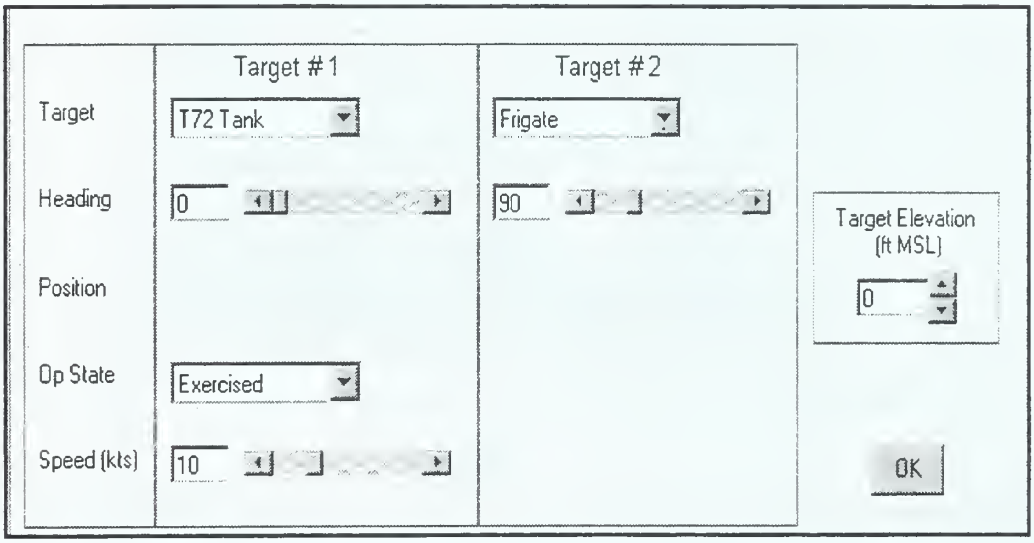
Parameter	**Desert Environment** Data from Reference 16 by Koch, Cynthia	**Maritime Environment** Data from Reference 13 by Fu-Chau, Liu
Surface Air Temperature	32 F	53 F
Surface dewpoint Temperature	28 F	48 F
Aerosol Index	5	12
Battlefield Induced contaminants	0 (none)	0 (None)
Visibility	15 nm	0 (None)
Precipitation Index	0 (None)	0 (None)
Rain Rate	0 (None)	0(None)
Wind Speed	15 knots	8 knots
Wind Direction	300 °	298 °
Boundary layer	400 hft	400 hft
Clouds	Type: Low Height: 300 hft Amount: 8	Type: Low Height: 300 hft Amount: 5

Table 4.3 Meteorological data set used for each Environment

The surface air temperature, surface dewpoint temperature, aerosol index, and visibility are used to compute an extinction coefficient. Extinction coefficient is used in IR, TV, and laser models. The extinction coefficients are used to compute the effect of incoming radiation and the efficiency of signal transmission from the target scene to the sensor. An extended explanation for each parameter in this form is enclosed in Appendix C (pag. 108-110).

The Ops data is entered using four different data entry forms: Sensor entry form, target entry form, target-location entry form, and background entry form. They are available by double clicking the descriptor picture in the main screen or from the drop down **Input** menu button.

The following Figure 4.5 shows the target entry form used in this case:



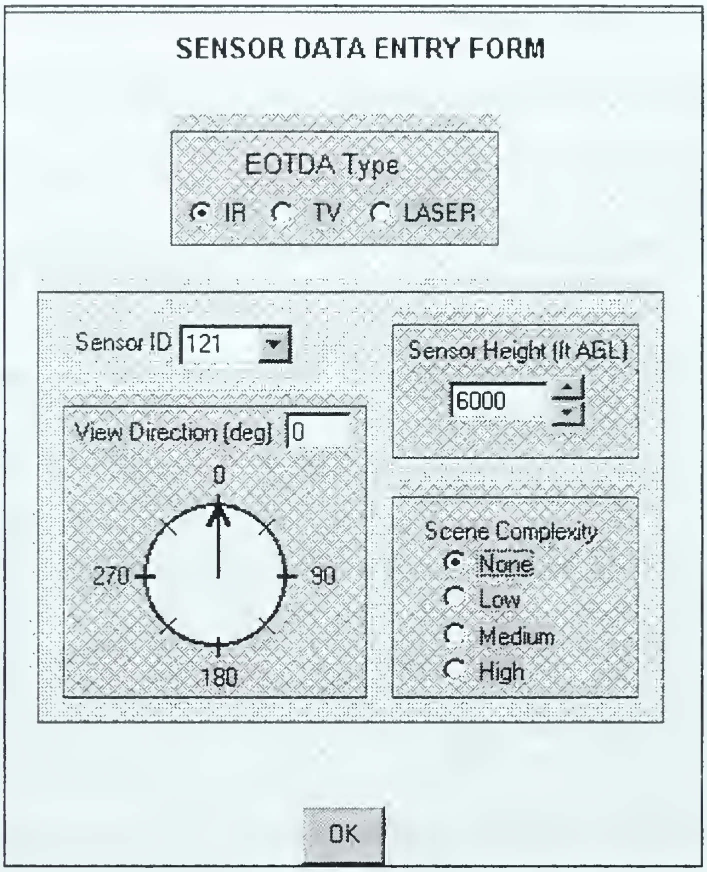
	Target #1	Target #2
Target	T72 Tank	Frigate
Heading	0	90
Position		
Op State	Exercised	
Speed (kts)	10	

Target Elevation (ft MSL): 0

Figure 4.5 WinEOTDA Target Data Entry Form

It shows a set of selected parameters for target #1: a T72, and also, the parameters for the target #2: a Frigate. Later, the target #2 was changed to a Gunboat for which the dimensions and characteristics are the same as the Research Vessel POINT SUR. A detailed description of the parameters on this Figure 4.5 is enclosed in the Appendix C (pag. 107).

The sensor entry form is represented with an aircraft on the main screen, double clicking on that picture will bring up the sensor form shown in Figure 4.6.



SENSOR DATA ENTRY FORM

EOTDA Type
● IR ○ TV ○ LASER

Sensor ID 121

Sensor Height (ft AGL) 6000

View Direction (deg) 0

Scene Complexity
● None
○ Low
○ Medium
○ High

Figure 4.6 WinEOTDA Sensor Data Entry Form

Since this thesis deals with IR sensors the selection was made between 25 different sensors. Also, a user-defined sensor # 150 was used with data obtained from the AN/AAA-36 physical parameters and theoretical values. The alphanumeric output shows the sensor data input for each run. See Appendix C (pag. 100-106).

The background data entry form is represented on the main screen by three rectangular boxes, with a generic picture of the selected background. Double clicking on each rectangular box brings up the following form:

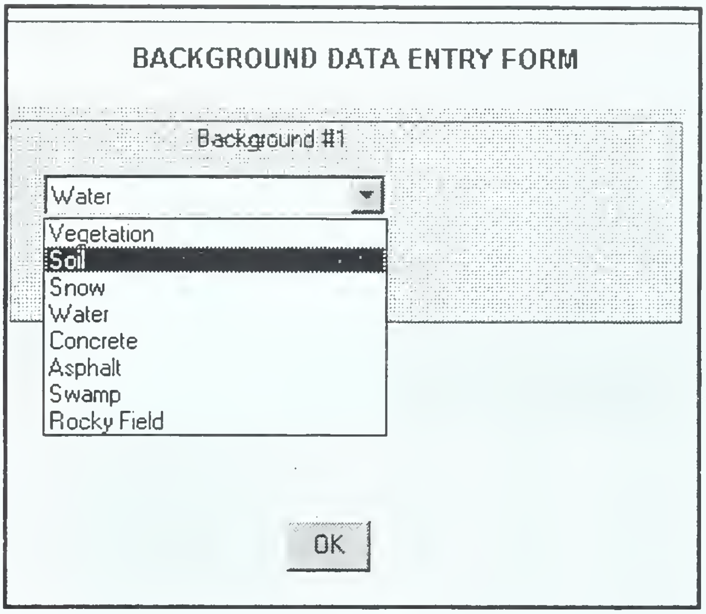


Figure 4.7 WinEOTDA Background Data Entry form

The background affects the target signature in several ways. One is that the background temperature is a factor in the hot/cold spot selection. Another is the impact of background temperature on target mean temperature. So, the first-listed background is considered a primary background and plays a singular role. In computing the ground radiation that is reflected, TCM2 takes only the primary background into consideration [Ref. 11:p. A-6]. Since this fact could be a source of error, the author set the same target

T72, as target #1 and target #2 for the first run; and the Gunboat, as target #1 and target#2 for the second run.

The position of the target is defined by the latitude and longitude coordinates. The location of the target is used in the calculations of solar position, lunar position, and temperature. The form for this parameter is found at the bottom left corner, just below the target pictures, on the main screen. The two selected scenarios were very well located by their geographical coordinates, as shown in Table 3.3 in the previous chapter.

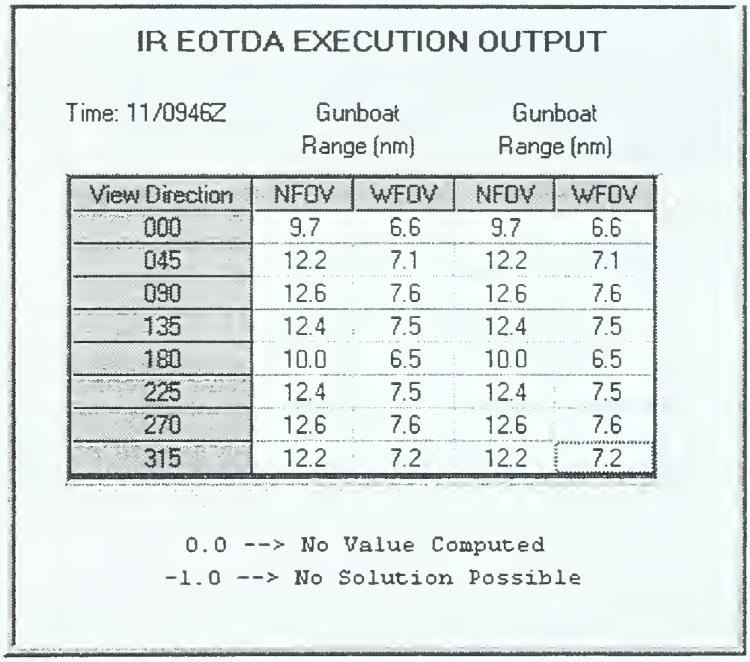
When all parameters are set, the code WinEOTDA was run. So, when the execution is completed, an indication of a successful run is presented at the bottom of the main screen. Then, in the center of the main screen a box appears with the predicted maximum range for those specific parameters.

E. WINEOTDA OUTPUTS

There are three possible ways to get data output from WinEOTDA: Alphanumeric, graphic and tabular output. After the run is completed, the code automatically generates all three kinds of output. Also, the WinEOTDA results are presented in a grid on the main screen (pag. 96). In this case, just the maximum ranges for each target against the selected backgrounds are presented. The user has the possibility to change the units in the main screen grid-output by clicking on the label containing the units. The options are kilo-feet (kft), kilometers (km) and nautical miles (nm).

Tabular Output provides WinEOTDA ranges in an easy to read format. For the IR model, ranges are displayed for each target for both Narrow and Wide Fields of View. The range displayed is the longest detection range, factoring in all backgrounds and both MDT and MRT.

The following Figure shows the **table/tabular output** for run # 8; the target is a Gunboat, the atmospheric conditions were set as a Maritime environment with strong continental influence and the user-defined sensor # 150 was used.



IR EOTDA EXECUTION OUTPUT

Time: 11/0946Z	Gunboat Range (nm)		Gunboat Range (nm)	
View Direction	NFOV	WFOV	NFOV	WFOV
000	9.7	6.6	9.7	6.6
045	12.2	7.1	12.2	7.1
090	12.6	7.6	12.6	7.6
135	12.4	7.5	12.4	7.5
180	10.0	6.5	10.0	6.5
225	12.4	7.5	12.4	7.5
270	12.6	7.6	12.6	7.6
315	12.2	7.2	12.2	7.2

```
0.0 --> No Value Computed
-1.0 --> No Solution Possible
```

Figure 4.8 WinEOTDA Tabular Output for run # 8

The user can graph the contents of the table by using the right mouse button anywhere on the table. The author chose the **000 and 090 VIEW DIRECTION** as the **FRONT** and **SIDE** aspect ratio in order to compare with the ACQUIRE results.

The Alphanumeric output is designed to permit creation of output products tailored to the user specific needs. All possible output products are created and are available for viewing. The code automatically produces output for the number of Fields of View (FOV) and the number of methods supported by the sensor. Since this output is too large a file to be shown here as a figure, it is enclosed as part of Appendix C (pag. 100-106).

The Graphic output is designed to display a template with one to four plots. Each plot is a single graph defined by an x- and y-axis. The plot contents define which targets, backgrounds, and FOV are displayed. A sample of this kind of output is enclosed in Appendix C (pag. 114).

F. RESULTS

This chapter contains all procedures and intermediate results that were obtained through this work. This last section will show the final results and the comparison between these two codes.

The Table 4.4 shows the predicted maximum ranges from ACQUIRE, assuming the required probability of detection based on the kind of ***task*** to be accomplished. Since WinEOTDA gives maximum range prediction only for detection, the remaining ACQUIRE results for ***classification, recognition and identification*** will be ignored for comparison purposes. However, a set of plots is presented as Figure 4.10 as a reference in order to show how ACQUIRE performs the different discrimination tasks.

As can be seen from the example in Figure 4.9, the results show some dependence on whether the sensor "sees" the target at Front or Side aspect. As was expected, the Side aspect presents greater values of range prediction, due of course to the increase in target-**critical dimension**.

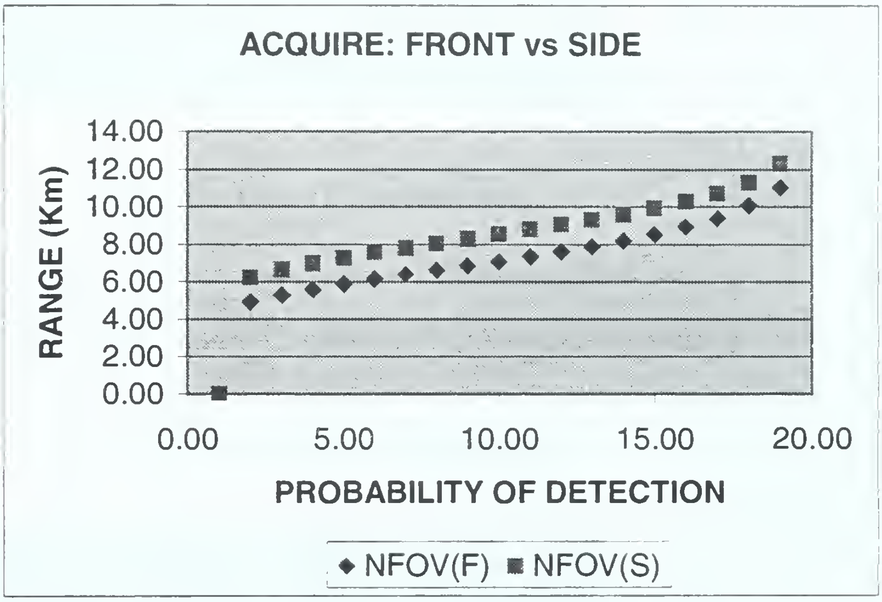


Figure 4.9 Relationship between Front and Side Aspect

Figure 4.10 compares the ACQUIRE predicted range versus probability of detection for the T72 target (4.10 a) and the Gunboat target (4.10 b). In both cases, ACQUIRE produces larger values in NFOVd (detection mode). Also can be noticed that there is a difference for each performed task.

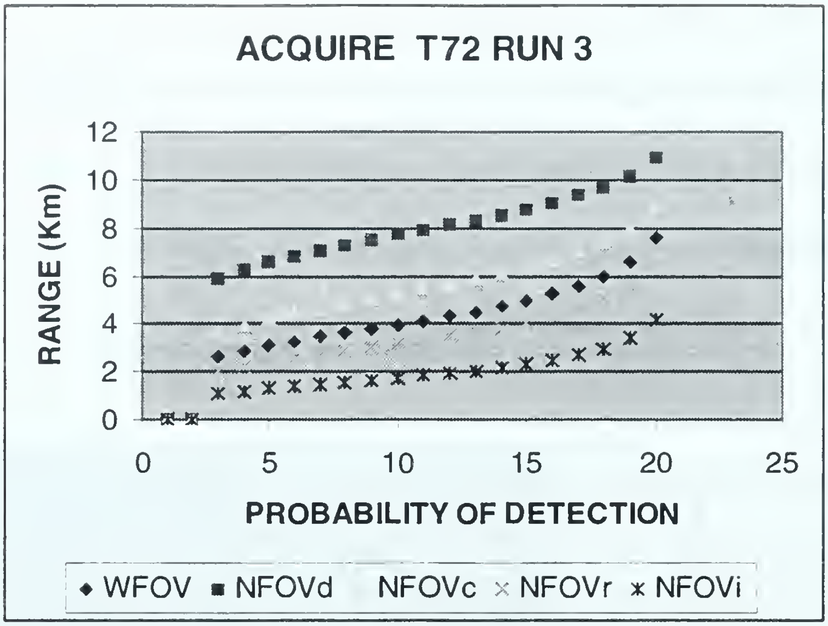


Figure 4.10 (a) ACQUIRE Output. T-72 as target, Front Aspect Desert Conditions, Sensor gen2

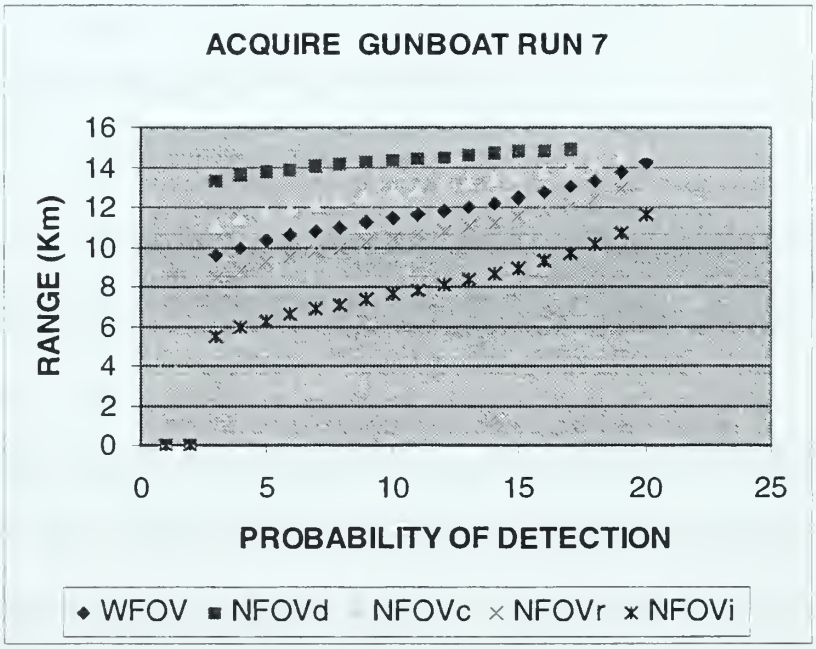


Figure 4.10 (b) ACQUIRE Output. Gunboat as target, Side Aspect Maritime Conditions, Sensor gen 1.

NOTE: NFOVd= Narrow Field of View for Detection.
NFOVr= Narrow Field of View for Recognition.
NFOVc= Narrow Field of View for Classification.
NFOVi= Narrow Field of View for Identification.

The observed range shown for each target, as well as the input weather conditions set for each specific environment, was based on an experiment at NAS Fallon, Nevada on January 9th, 1996 [Ref.16] and the PREOS92 experiment off the Monterey Coastline on August 4th, 1992 [Ref.13].

ACQUIRE					
OBSERVED RANGE		**12.67 Km**		**17 Km**	
		T-72		**GUNBOAT**	
		WFOV	**NFOV**	**WFOV**	**NFOV**
GEN 1	F	6.07	11.04	12.67	14.82
	S	8.09	12.31	14.27	14.92
GEN 2	F	7.57	10.92	12.36	12.59
	S	8.72	11.11	12.59	12.47
NACIT9	F	4.89	9.50	11.43	14.56
	S	6.30	10.96	13.67	14.97

Table 4.4 DETECTION Predicted Ranges in Km (Maximum)

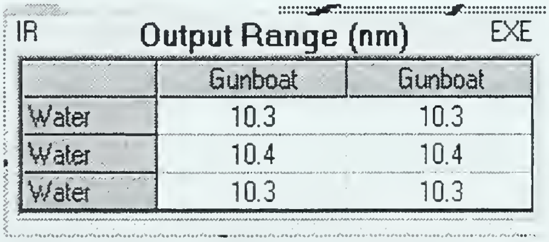
We see that the predicted ranges are in reasonable agreement to the observed range. The precise identification of the FLIR sensor used for the observation is not known. The generic sensors represented by the models gen1, gen2, and NACIT9 differ and cause variation in the predictions. For the Gunboat target all three under predict, but gen1 NFOV and NACIT9 NFOV show the closest agreement and approximately equal values. For the T-72 in the desert environment gen1 NFOV gives the closest agreement. The agreement for the selected model is of order 20%.

When the same targets and scenarios are modeled with WinEOTDA, the results show close to the same values. Of course, the output presentation and parameters are different, as was shown previously.

The predicted ranges from WinEOTDA are mainly affected by the target operating state (not considered by ACQUIRE) and by the target heading. However, the difference (in range) is negligible. Also, as was pointed out, the backgrounds play an important role in this code performance.

The backgrounds were selected according to the specific area and typical operating conditions of those targets. So, for example, for the T72 in desert conditions a Generic Soil Background was selected. Three parameters define the characteristic of this background: Type, Surface Moisture and Depth Moisture. The three parameters influence solar loading, evaporation and condensation, soil temperature, and convection. [Ref. 11] Different combinations of these three parameters were set in order to see how each target was affected. The results showed that the difference was real but small.

Figure 4.11 shows the slight difference occurring when a combination of target parameters (operating state and heading) and background parameters was set. The difference, less than 1%, is negligible, for practical purpose.



Output Range (nm)

	Gunboat	Gunboat
Water	10.3	10.3
Water	10.4	10.4
Water	10.3	10.3

Figure 4.11 WinEOTDA Output (different backgrounds)

The following Table 4.5 summarizes the WinEOTDA results, for this model we see closer agreement with the observed values. Again gen1 sensor shows best performance with NACIT9 second, and again NFOV is the better mode.

WinEOTDA					
OBSERVED RANGE		**12.67 Km**		**17 Km**	
		T-72		**GUNBOAT**	
		WFOV	**NFOV**	**WFOV**	**NFOV**
GEN 1 (151)	F	7.2	12.5	12.3	13.5
	S	8.0	12.7	17.0	17.3
GEN 2 (152)	F	3.8	10.6	13.02	14.6
	S	5.2	10.6	17.2	19.7
NACIT9 (150)	F	4.7	9.9	7.9	14.0
	S	4.1	10.5	9.5	17.5

Table 4.5 DETECTION Predicted Ranges in Km (Maximum)

Generally speaking, the WinEOTDA values for the Gunboat target are closer to the reference than those for the T-72. It is possible that the aerosol model is better defined for the Maritime environment than the desert aerosol model. Gathering the values in a more explicit format, it can be noted that WinEOTDA values are slightly closer to the reference than those obtained by using ACQUIRE. The selected models show less than 10% difference.

Table 4.6 shows a comparison of average values as a percentage of the observed range for the two models.

Predicted Range as Percentage of Observed Range									
		ACQUIRE				**WinEOTDA**			
		Tank T72		**Gunboat**		**Tank T72**		**Gunboat**	
		WFOV	NFOV	WFOV	NFOV	WFOV	NFOV	WFOV	NFOV
GEN 1	F	47.9	87.1	74.5	87.2	56.8	98.7	72.4	79.4
	S	63.8	97.2	83.9	87.8	63.1	100.2	100	100.2
GEN 2	F	59.7	86.2	72.7	74.1	29.9	83.7	76.6	85.9
	S	68.8	87.7	74.06	73.3	41.0	83.7	101.2	115.9
NACIT 9	F	38.6	75.0	67.2	85.6	37.1	78.1	46.5	82.3
	S	49.7	86.5	80.4	88.1	32.4	82.9	55.9	102.9

Table 4.6 Predicted Range as Percentage of Observed Range

The code predictions must be expected to show longer ranges for the NFOV than the WFOV, since the MRT shows lower values and asymptote at larger spatial frequencies for the NFOV. Similarly we expect the predicted ranges to be longer for the side aspect that the Front aspect. We notice from Table 4.6 that gen1 sensor gave closer agreement for both codes and targets, especially in NFOV mode. Also, we can see different results when targets are in Front or Side aspect. As we expected for the Side aspect the values are longer than those from Front aspect are.

We see both codes have better performance in NFOV. Also, we can see the slight difference between the two codes. WinEOTDA in NFOV using the Gunboat as target, is just one mile from the observed range.

V. CONCLUSIONS AND RECOMENDATIONS

A. SUMMARY

This work has presented an opportunity to compare the performance and ease of use of two Tactical Decision Aids developed for the US Army and US Air Force/Navy applied to equivalent targets for each of two scenarios representing land and sea environments. This leads to consideration of cross-utilization of either or both by all services, an important concept in the arena of Joint Operations.

The different means by which the two codes modeled the target and background, meteorological conditions, and sensor performance were presented and compared. The final topic was a direct comparison of the two models based on predicted target detection ranges from the two codes for equivalent operator inputs.

B. CONCLUSIONS

ACQUIRE and WinEOTDA are Tactical Decision Aids that can help to make an appropriate decision under any operational and environmental conditions. Of course, differences in handling required parameters make a large difference between these codes.

ACQUIRE, for example, requires a trained operator with clear ideas about IR theory and the operation of the code. On the other hand, WinEOTDA is practically as easy to use as any other Windows application. Just click on the main screen and you get a drop down menu with the available options. While WinEOTDA is more user friendly, ACQUIRE requires written programs in specific format in order to run.

Although ACQUIRE was designed for small land targets, it performs an excellent job against the Gunboat, and WinEOTDA did the same. Both codes gave only slight deviations in predicted ranges. So, if we get the appropriate data: weather conditions updated, the characteristics of the target (intelligence sources) and one of these codes we can obtain our operational useful range for using the most sophisticated weapons system available.

While the absolute accuracy of the prediction codes cannot be determined in this study for classification reasons, the qualitative comparison will provide a convenient tutorial introduction for selection of a TDA for specific operational needs.

C. RECOMMENDATIONS

Each of the codes can be used as a TDA for any military service. However, some minor modifications can improve a lot the accuracy and precision of the predicted ranges. For example, ACQUIRE requires a friendly interface to make it easy to work with, for non-professional analysts, and additional target and sensor files should be added. WinEOTDA has the flexibility and friendly operational interface but it needs some computer resources to become available.

Since the weather conditions of the target area are needed to improve the accuracy of the predicted range, the better the meteorological data we get, the more precise the predicted range is.

The overall result shows satisfactory values, however the author believes that there were too few values to validate one of them over the other one. It would be necessary to perform further analyses and operational validations to choose a standard TDA for Joint Operations.

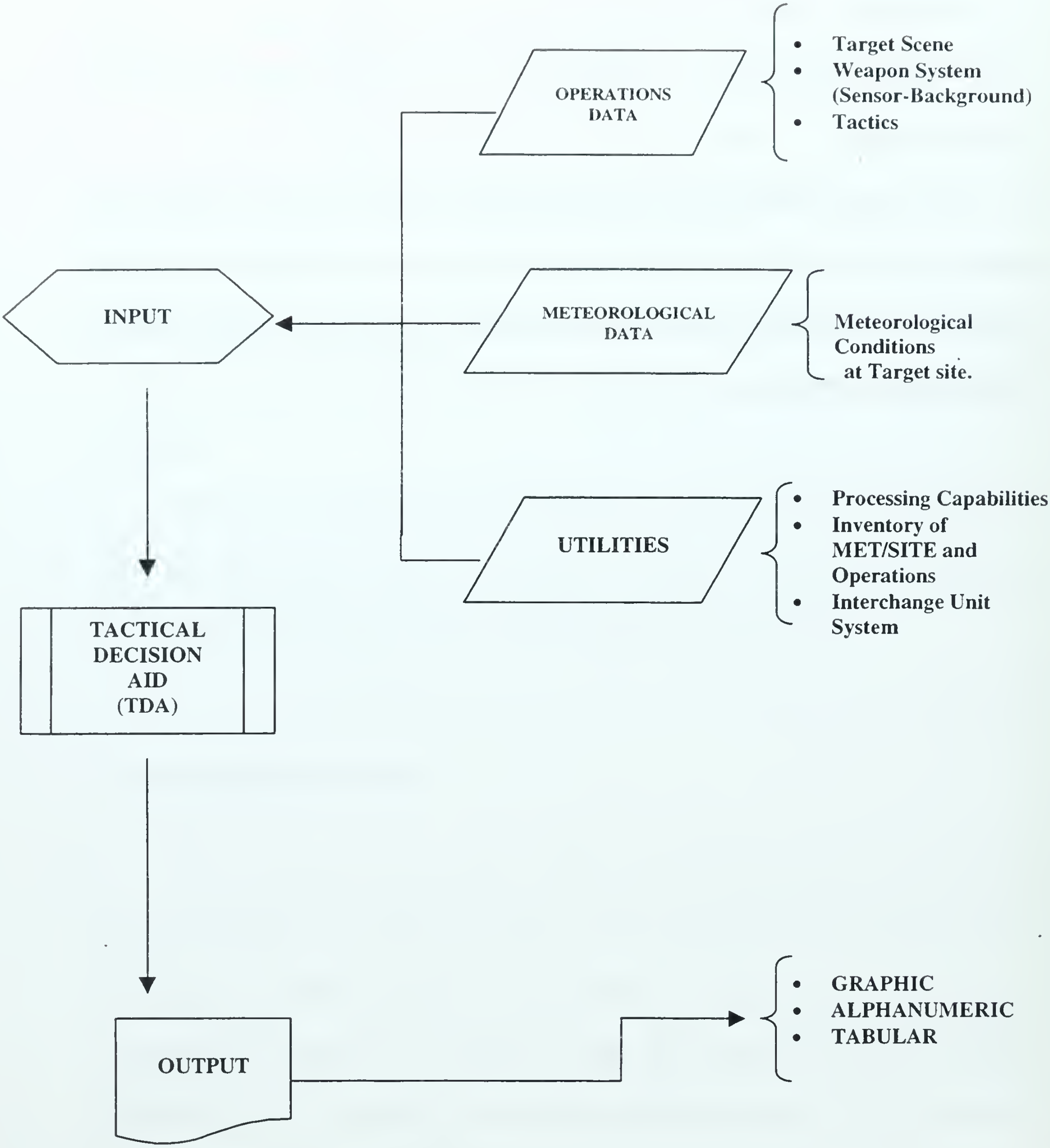


Figure 3.1 Functional Diagram of a general TDA

DATA INPUT FOR TARGET T-72 AT NAS FALLON, NEVADA

PANEL NUMBER	PANEL DESCRIPTION	DATA INPUT SELECTED
PANEL 1	ATMOSPHERIC MODEL	MIDLATITUDE SUMMER
PANEL 2	RAY PATH GEOMETRY	SLANT PATH BETWEEN TWO ALTITUDES
PANEL 3	PROGRAM OPERATION MODE	TRANSMITTANCE
PANEL 4	*TEMP/PRES/WATER VAPOR PROFILES. *RADIOSONDA DATA	NORMAL OPERATION NONE
PANEL 5	EXTINTION TYPE	URBAN EXTINTION, 5 km VIS
PANEL 6	SEASONAL DEPENDANCE PROFILE	DEFAULT TO THE SEASON OF THE MODEL
PANEL 7	TRANSITION PROFILE	DEFAULT
PANEL 8	AIR MASS CHARACTER	NO APPLIED
PANEL 9	*CLOUDS ATTENUATION *ARMY VERTICAL ALGORITHM (VSA)	NO CIRRUS CLOUD ATTENUATION NOT USED
PANEL 10	WIND SPEED	NOT USED
PANEL 11	PRECIPITATION RATE	0.1 mm
PANEL 12	ALTITUDE (INITIAL/FINAL/PATH)	(0.01/0.5/0.5-30) Km
PANEL 13	RADIUS OF THE EARTH	NORMAL OPERATION
PANEL 14	SPECTRAL RANGE	833.33/1250/20 (cm^{-1})
PANEL 15	REPEAT/END	REPEAT 20 TIMES (MODIFIED PATH)

TABLE 3.7 TARGET T-72 PARAMETER SET FOR LOWTRAN 6

DATA INPUT FOR TARGET GUNBOAT AT MONTEREY COAST,CALIFORNIA

PANEL NUMBER	PANEL DESCRIPTION	DATA INPUT SELECTED
PANEL 1	ATMOSPHERIC MODEL	MIDLATITUDE SUMMER
PANEL 2	RAY PATH GEOMETRY	SLANT PATH BETWEEN TWO ALTITUDES
PANEL 3	PROGRAM OPERATION MODE	TRANSMITTANCE
PANEL 4	*TEMP/PRES/WATER VAPOR PROFILES. *RADIOSONDA DATA	NORMAL OPERATION NONE
PANEL 5	EXTINTION TYPE	NAM (Navy Aerosol Model)
PANEL 6	SEASONAL DEPENDANCE PROFILE	DEFAULT TO THE SEASON OF THE MODEL
PANEL 7	TRANSITION PROFILE	DEFAULT
PANEL 8	AIR MASS CHARACTER	VALUE = 3
PANEL 9	*CLOUDS ATTENUATION *ARMY VERTICAL ALGORITHM (VSA)	NO CIRRUS CLOUD ATTENUATION NOT USED
PANEL 10	WIND SPEED	5 m/s
PANEL 11	PRECIPITATION RATE	0.1 mm
PANEL 12	ALTITUDE (INITIAL/FINAL/PATH)	(0.01/0.5/0.5-30) Km
PANEL 13	RADIUS OF THE EARTH	NORMAL OPERATION
PANEL 14	SPECTRAL RANGE	833.33/1250/20 (cm^{-1})
PANEL 15	REPEAT/END	REPEAT 20 TIMES (MODIFIED PATH)

TABLE 3.8 TARGET GUNBOAT PARAMETER SET FOR LOWTRAN 6

MRTD COMPUTATIONS

	From Shumaker Ex. 8		...New Value
NET=	0.1	0.3	0.14
DAS=	0.25	1	0.45

SL=	0.0075	0.0225	0.0105
SC=	0.0325	0.39	0.0819
ER=	0.625	2.5	1.125

f		0.25mRad	1mRad	0.45mRad
0.1	MRT=	0.010018	0.057341	0.017026
0.2		0.012722	0.120642	0.024775
0.3		0.015714	0.268442	0.034768
0.4		0.019114	0.675595	0.048469
0.5		0.023063	1.978021	0.068144
0.6		0.027737	6.835714	0.097468
0.7		0.033359	28.12041	0.142616
0.8		0.040214	138.4451	0.214273
0.96		0.054719	2599.65	0.436981
1.38		0.133215	56697152	4.230673
1.65		0.255343	2.07E+11	25.26968
2.6		4.520145	5.29E+28	117881.7
3.1		30.45667	8.93E+40	40226927

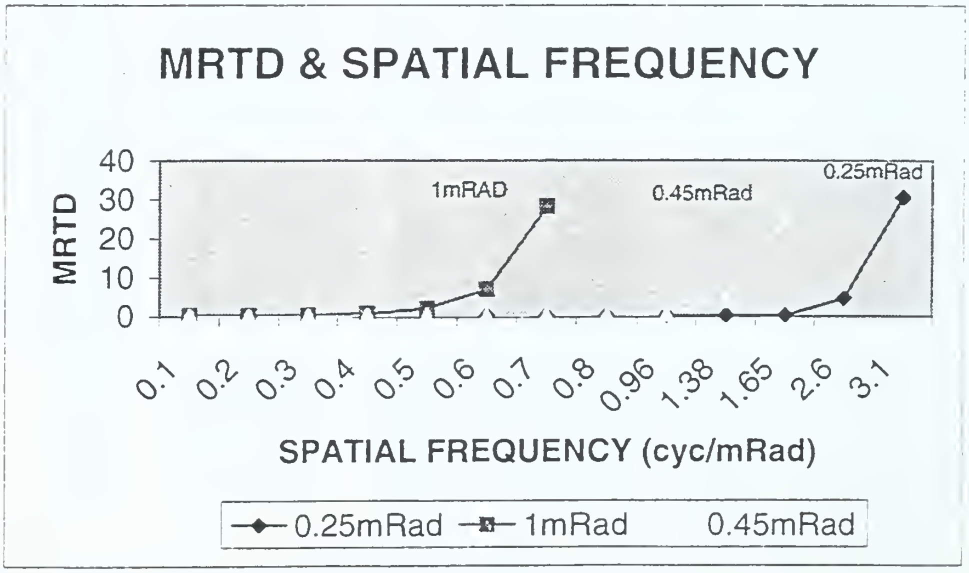


Figure 4.1. Excel Spreadsheet. MRTD Computations

APPENDIX A. PROPORTIONAL RADIATION TABLE

The Proportional Radiation Table.

The "Proportional Radiation", $q = f(\lambda.T)$ represents the fraction of the radiant exitance which is emitted by a blackbody at temperature T at all wavelengths up to the selected value of λ. It is obtained from the integral over the Planck Law for wavelengths up to the selected value divided by the integral over all wavelengths, ie

$$q = \frac{\int_0^{\lambda} M(\lambda T)\, d\lambda}{\int_0^{\infty} M(\lambda T)\, d\lambda}$$

$\frac{\lambda.T}{cm.K}$	q	$\frac{\lambda.T}{cm.K}$	q	$\frac{\lambda.T}{cm.K}$	q
0.050	$1.3652.10^{-9}$	0.140	$7.9053.10^{-3}$	0.460	$5.8057.10^{-1}$
0.052	$3.6788.10^{-9}$	0.150	$1.3023.10^{-2}$	0.480	$6.0880.10^{-1}$
0.054	$9.1749.10^{-9}$	0.160	$1.9962.10^{-2}$	0.500	$6.3494.10^{-1}$
0.056	$2.1358.10^{-8}$	0.170	$2.8858.10^{-2}$	0.520	$6.5912.10^{-1}$
0.058	$4.6745.10^{-8}$	0.180	$3.9754.10^{-2}$	0.540	$6.8146.10^{-1}$
0.060	$9.6798.10^{-8}$	0.190	$5.2613.10^{-2}$	0.560	$7.0209.10^{-1}$
0.062	$1.9069.10^{-7}$	0.200	$6.7331.10^{-2}$	0.580	$7.2116.10^{-1}$
0.064	$3.5907.10^{-7}$	0.210	$8.3750.10^{-2}$	0.600	$7.3877.10^{-1}$
0.066	$6.4902.10^{-7}$	0.220	$1.0168.10^{-1}$	0.620	$7.5505.10^{-1}$
0.068	$1.1302.10^{-6}$	0.230	$1.2091.10^{-1}$	0.660	$7.8402.10^{-1}$
0.070	$1.9025.10^{-6}$	0.240	$1.4122.10^{-1}$	0.700	$8.0885.10^{-1}$
0.072	$3.1045.10^{-6}$	0.250	$1.6239.10^{-1}$	0.740	$8.3020.10^{-1}$
0.074	$4.9236.10^{-6}$	0.260	$1.8423.10^{-1}$	0.780	$8.4861.10^{-1}$
0.076	$7.6070.10^{-6}$	0.270	$2.0653.10^{-1}$	0.820	$8.6455.10^{-1}$
0.078	$1.1473.10^{-5}$	0.280	$2.2911.10^{-1}$	0.860	$8.7840.10^{-1}$
0.080	$1.6923.10^{-5}$	0.290	$2.5183.10^{-1}$	0.900	$8.9048.10^{-1}$
0.082	$2.4453.10^{-5}$	0.300	$2.7454.10^{-1}$	0.940	$9.010\#.10^{-1}$
0.084	$3.4668.10^{-5}$	0.310	$2.9712.10^{-1}$	0.980	$9.1033.10^{-1}$
0.086	$4.8287.10^{-5}$	0.320	$3.1947.10^{-1}$	1.00	$9.1455.10^{-1}$
0.088	$6.6159.10^{-5}$	0.330	$3.4150.10^{-1}$	1.10	$9.3217.10^{-1}$
0.090	$8.9269.10^{-5}$	0.340	$3.6314.10^{-1}$	1.20	$9.4532.10^{-1}$
0.092	$1.1874.10^{-4}$	0.350	$3.8432.10^{-1}$	1.30	$9.5331.10^{-1}$
0.094	$1.5586.10^{-4}$	0.360	$4.0502.10^{-1}$	1.40	$9.6304.10^{-1}$
0.096	$2.0204.10^{-4}$	0.370	$4.2518.10^{-1}$	1.50	$9.6909.10^{-1}$
0.098	$2.5885.10^{-4}$	0.380	$4.4479.10^{-1}$	1.60	$9.7390.10^{-1}$
0.100	$3.2804.10^{-4}$	0.390	$4.6382.10^{-1}$	1.70	$9.7777.10^{-1}$
0.110	$9.2957.10^{-4}$	0.400	$4.8227.10^{-1}$	1.80	$9.8091.10^{-1}$
0.120	$2.1727.10^{-3}$	0.420	$5.1738.10^{-1}$	1.90	$9.8349.10^{-1}$
0.130	$4.3866.10^{-3}$	0.440	$5.5012.10^{-1}$	2.00	$9.8563.10^{-1}$

Adapted from "Optoelectronics; Theory and Practice" A. Chappell. Ed., McGraw-Hill Book Company, 1978.

APPENDIX B. ACQUIRE SAMPLE OUTPUT

The following pages are included as an appendix B. The pages show the programs and the output files from ACQUIRE. Appendix B contents program runs and figures:

	Page Number
Run #1	66
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```
                                                Sun Aug  9 15:10:19 1998

run #1
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)
data file: NACIT1
command line:  -d NACIT1

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

NACIT1: DATA INPUT FOR ACQUIRE: TARGET T-72 DESERT CONDITIONS.
      >sensor_lookup
                data_file_name             sensor.dat   ---
                sensor_id                  gen1         ---
                performance_mode           MRT        MRT_MDT_MRC_OR_MDC

      >target_lookup
                target_id                       T72    ---
                aspect                          f      F_or_S
                target_signature                1.25   degrees_C

        >cycle_criteria
                detection_n50                  0.75     wfov
                detection_n50                  0.75     nfov
                classification_n50             1.5      nfov
                recognition_n50                3.0      nfov
                identification_n50             6.0      nfov

        >band-averaged_atmosphere
                #_points: 20    km............transmittance
                                0.000e+00     1.000e+00
                                5.000e-01     8.175e-01
                                7.500e-01     7.515e-01
                                1.000e+00     6.927e-01
                                2.000e+00     5.082e-01
                                3.000e+00     3.778e-01
                                4.000e+00     2.830e-01
                                5.000e+00     2.130e-01
                                6.000e+00     1.610e-01
                                8.000e+00     0.927e-01
                                1.000e+01     0.537e-01
                                1.200e+01     0.313e-01
                                1.400e+01     0.183e-01
                                1.600e+01     0.108e-02
                                1.800e+01     0.063e-02
                                2.000e+01     0.037e-02
                                2.200e+01     0.022e-02
                                2.400e+01     0.013e-02
                                2.600e+01     0.007e-02
                                2.800e+01     0.004e-02
      >repeat
end parameter listing...
```

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad       MRTD
                2.970e-001     1.020e-002
                4.300e-001     1.460e-002
                5.990e-001     2.100e-002
                8.200e-001     3.020e-002
                1.091e+000     4.340e-002
                1.390e+000     6.230e-002
                1.692e+000     8.960e-002
                1.987e+000     1.288e-001
                2.265e+000     1.851e-001
                2.522e+000     2.660e-001
                2.754e+000     3.823e-001
                2.959e+000     5.494e-001
                3.148e+000     7.896e-001
                3.300e+000     1.135e+000
                3.440e+000     1.631e+000
                3.567e+000     2.344e+000
                3.649e+000     3.369e+000
                3.723e+000     4.841e+000
                3.778e+000     6.958e+000
                3.834e+000     1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.


SENSOR

      gen1 from sensor.dat


TARGET

      T72 F aspect (2.55 meters)
      inherent signature: 1.25 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                 WFOV        NFOV        NFOV        NFOV        NFOV
   prob       N50=0.75    N50=0.75    N50=1.50    N50=3.00    N50=6.00
  ------     ----------  ----------  ----------  ----------  ----------
   0.95        1.70 km     4.37 km     2.46 km     1.30 km     0.65 km
   0.90        1.96        4.92        2.81        1.50        0.77
   0.85        2.15        5.29        3.07        1.66        0.86
   0.80        2.32        5.60        3.30        1.79        0.93
   0.75        2.48        5.88        3.50        1.91        1.00
   0.70        2.62        6.15        3.70        2.03        1.07
   0.65        2.76        6.40        3.88        2.14        1.13
   0.60        2.91        6.62        4.06        2.26        1.20
   0.55        3.05        6.85        4.25        2.38        1.27
   0.50        3.21        7.09        4.44        2.51        1.34
   0.45        3.38        7.35        4.65        2.64        1.41
   0.40        3.56        7.62        4.88        2.79        1.50
   0.35        3.76        7.88        5.12        2.95        1.59
   0.30        3.98        8.17        5.38        3.14        1.70
   0.25        4.24        8.52        5.69        3.37        1.83
   0.20        4.56        8.93        6.08        3.65        2.00
   0.15        5.00        9.39        6.56        4.01        2.23
   0.10        5.59       10.05        7.22        4.55        2.58
   0.05        6.67       11.04        8.34        5.54        3.25

end of run 1 from NACIT1



                                          Sun Aug  9 15:10:19 1998

run #2
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: NACIT1
command line:  -d NACIT1


TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

     >target_lookup
              target_id                      T72     ---
              aspect                         S        F_or_S
              target_signature               1.25     degrees_C

       >end


end parameter listing...
```

RUN # 1

SENSOR: GEN 1

T-72 FRONT ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	1.70 km	4.37 km	2.46 km	1.3 km	0.65 km
0.90	1.96	4.92	2.81	1.50	0.77
0.85	2.15	5.29	3.07	1.66	0.86
0.80	2.32	5.60	3.30	1.79	0.93
0.75	2.48	5.88	3.50	1.91	1.00
0.70	2.62	6.15	3.70	2.03	1.07
0.65	2.76	6.40	3.88	2.14	1.13
0.60	2.91	6.62	4.06	2.26	1.20
0.55	3.05	6.85	4.25	2.38	1.27
0.50	3.21	7.09	4.44	2.51	1.34
0.45	3.38	7.35	4.65	2.64	1.41
0.40	3.56	7.62	4.88	2.79	1.50
0.35	3.76	7.88	5.12	2.95	1.59
0.30	3.98	8.17	5.38	3.14	1.70
0.25	4.24	8.52	5.69	3.37	1.83
0.20	4.56	8.93	6.08	3.65	2.00
0.15	5.00	9.39	6.56	4.01	2.23
0.10	5.59	10.05	7.22	4.55	2.58
0.05	6.67	11.04	8.34	5.54	3.25

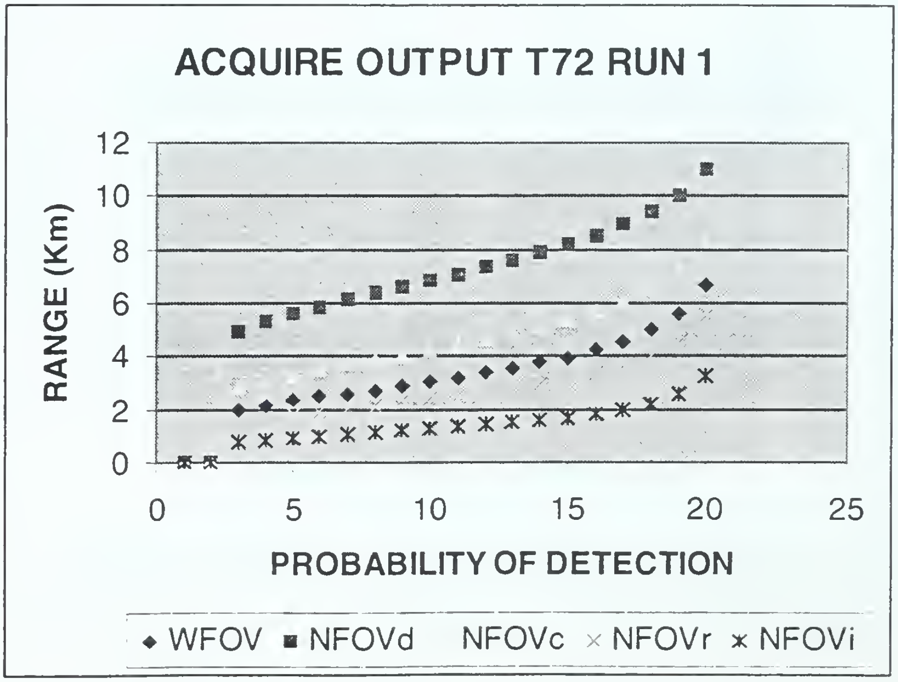


Figure B.1 Range Performance T72. Run 1 (Excel sheet)

```
MESSAGES

      No change in system demand function
      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.


SENSOR
      gen1 from sensor.dat

TARGET

      T72 S aspect (3.6 meters)
      inherent signature: 1.25 degrees C

OBSERVER ENSEMBLE PERFORMANCE


RANGE GIVEN PROBABILITY...
               WFOV        NFOV        NFOV        NFOV        NFOV
    prob     N50=0.75    N50=0.75    N50=1.50    N50=3.00    N50=6.00
   ------   ----------  ----------  ----------  ----------  ----------
    0.95       2.33 km     5.62 km     3.30 km     1.80 km     0.92 km
    0.90       2.67        6.23        3.76        2.06        1.08
    0.85       2.92        6.64        4.08        2.27        1.20
    0.80       3.13        6.97        4.35        2.45        1.29
    0.75       3.33        7.27        4.59        2.61        1.39
    0.70       3.52        7.56        4.83        2.75        1.47
    0.65       3.70        7.81        5.06        2.90        1.56
    0.60       3.88        8.04        5.26        3.05        1.65
    0.55       4.06        8.27        5.47        3.20        1.74
    0.50       4.24        8.52        5.70        3.37        1.83
    0.45       4.44        8.78        5.93        3.54        1.94
    0.40       4.66        9.04        6.19        3.73        2.05
    0.35       4.91        9.29        6.46        3.93        2.18
    0.30       5.17        9.57        6.74        4.16        2.33
    0.25       5.46        9.91        7.07        4.43        2.50
    0.20       5.83       10.29        7.49        4.77        2.72
    0.15       6.32       10.72        7.97        5.20        3.01
    0.10       6.96       11.31        8.65        5.81        3.46
    0.05       8.09       12.31        9.74        6.90        4.29


end of run 2 from NACIT1
```

RUN # 2
SENSOR: GEN 1 T-72 SIDE ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	2.33 km	5.62 km	3.30 km	1.8 km	0.92 km
0.90	2.67	6.23	3.76	2.06	1.08
0.85	2.92	6.64	4.08	2.27	1.20
0.80	3.13	6.97	4.35	2.45	1.29
0.75	3.33	7.27	4.59	2.61	1.39
0.70	3.52	7.56	4.83	2.75	1.47
0.65	3.70	7.81	5.06	2.90	1.56
0.60	3.88	8.04	5.26	3.05	1.65
0.55	4.06	8.27	5.47	3.20	1.74
0.50	4.24	8.52	5.70	3.37	1.83
0.45	4.44	8.78	5.93	3.54	1.94
0.40	4.66	9.04	6.19	3.73	2.05
0.35	4.91	9.29	6.46	3.93	2.18
0.30	5.17	9.57	6.74	4.16	2.33
0.25	5.46	9.91	7.07	4.43	2.50
0.20	5.83	10.29	7.49	4.77	2.72
0.15	6.32	10.72	7.97	5.20	3.01
0.10	6.96	11.31	8.65	5.81	3.46
0.05	8.09	12.31	9.74	6.90	4.29

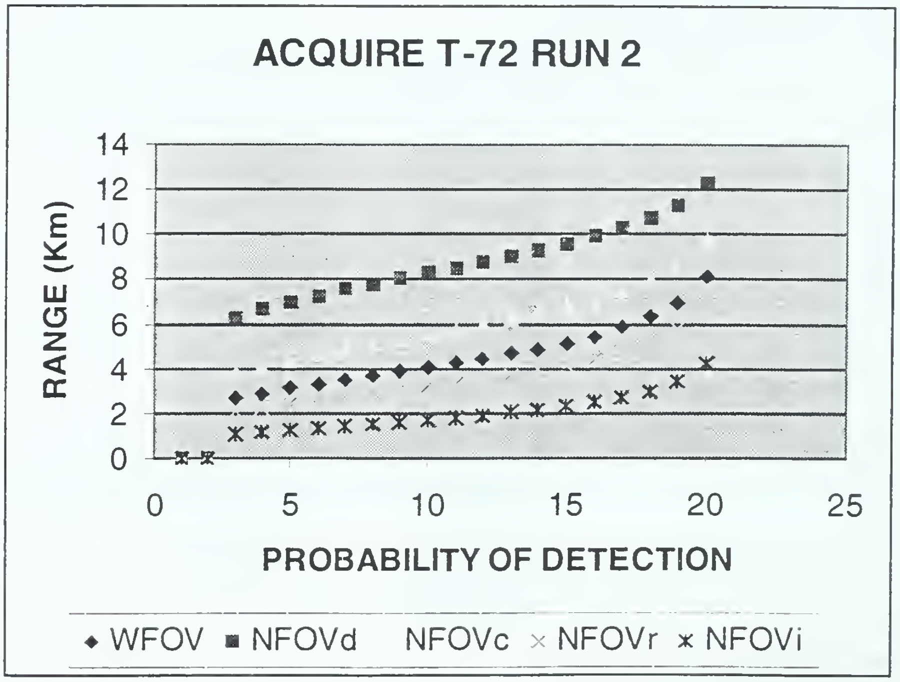


Figure B.2. Range Performance T72. Run 2 (Excel sheet)

```
                                                 Sun Aug  9 15:13:01 1998

run #3
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)
data file: NACIT11
command line:  -d NACIT11

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

NACIT11: DATA INPUT FOR ACQUIRE: TARGET T-72 DESERT CONDITIONS.
      >sensor_lookup
                data_file_name             sensor.dat    ---
                sensor_id                  gen2          ---
                performance_mode           MRT         MRT_MDT_MRC_OR_MDC

      >target_lookup
                target_id                        T72    ---
                aspect                           f       F_or_S
                target_signature                 1.25    degrees_C

        >cycle_criteria
                detection_n50                   0.75     wfov
                detection_n50                   0.75     nfov
                classification_n50              1.5      nfov
                recognition_n50                 3.0      nfov
                identification_n50              6.0      nfov

        >band-averaged_atmosphere
                #_points: 20    km............transmittance
                                0.000e+00     1.000e+00
                                5.000e-01     8.175e-01
                                7.500e-01     7.515e-01
                                1.000e+00     6.927e-01
                                2.000e+00     5.082e-01
                                3.000e+00     3.778e-01
                                4.000e+00     2.830e-01
                                5.000e+00     2.130e-01
                                6.000e+00     1.610e-01
                                8.000e+00     0.927e-01
                                1.000e+01     0.537e-01
                                1.200e+01     0.313e-01
                                1.400e+01     0.183e-01
                                1.600e+01     0.108e-02
                                1.800e+01     0.063e-02
                                2.000e+01     0.037e-02
                                2.200e+01     0.022e-02
                                2.400e+01     0.013e-02
                                2.600e+01     0.007e-02
                                2.800e+01     0.004e-02

      >repeat
end parameter listing...
```

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad        MRTD
                9.040e-001     4.090e-002
                1.254e+000     5.460e-002
                1.640e+000     7.300e-002
                2.054e+000     9.750e-002
                2.466e+000     1.302e-001
                2.855e+000     1.739e-001
                3.216e+000     2.323e-001
                3.548e+000     3.102e-001
                3.853e+000     4.143e-001
                4.129e+000     5.534e-001
                4.383e+000     7.392e-001
                4.613e+000     9.873e-001
                4.828e+000     1.319e+000
                5.015e+000     1.761e+000
                5.192e+000     2.352e+000
                5.347e+000     3.142e+000
                5.483e+000     4.197e+000
                5.611e+000     5.605e+000
                5.722e+000     7.487e+000
                5.807e+000     1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 11.8 km, extend
      curve to lower frequencies and temperatures.



SENSOR

      gen2 from sensor.dat


TARGET

      T72 F aspect (2.55 meters)
      inherent signature: 1.25 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                 WFOV          NFOV          NFOV          NFOV          NFOV
   prob       N50=0.75      N50=0.75      N50=1.50      N50=3.00      N50=6.00
  ------     ----------    ----------    ----------    ----------    ----------
   0.95        2.31 km       5.40 km       3.25 km       1.79 km       0.92 km
   0.90        2.63          5.92          3.67          2.05          1.08
   0.85        2.87          6.30          3.97          2.25          1.20
   0.80        3.08          6.60          4.23          2.42          1.29
   0.75        3.27          6.85          4.46          2.57          1.39
   0.70        3.45          7.08          4.66          2.72          1.47
   0.65        3.61          7.30          4.86          2.86          1.56
   0.60        3.78          7.52          5.06          3.00          1.64
   0.55        3.95          7.71          5.26          3.15          1.73
   0.50        4.13          7.90          5.47          3.31          1.82
   0.45        4.32          8.10          5.67          3.47          1.93
   0.40        4.52          8.32          5.89          3.64          2.04
   0.35        4.73          8.55          6.13          3.83          2.16
   0.30        4.97          8.78          6.39          4.05          2.31
   0.25        5.25          9.03          6.69          4.31          2.48
   0.20        5.59          9.34          7.02          4.61          2.69
   0.15        6.00          9.71          7.45          5.00          2.96
   0.10        6.60         10.17          8.00          5.57          3.39
   0.05        7.57         10.92          8.91          6.54          4.17

end of run 3 from NACIT11



                                                Sun Aug  9 15:13:02 1998

run #4
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: NACIT11
command line:  -d NACIT11

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

      >target_lookup
                target_id                       T72     ---
                aspect                          S       F_or_S
                target_signature                1.25    degrees_C

        >end



end parameter listing...
```

RUN #3
SENSOR: GEN 2

T-72 FRONT ASPECT

Prob	WFOV N50=0.75	NFOVd N50=0.75	NFOVc N50=1.5	NFOVr N50=3.0	NFOVi N50=6.0
0.95	2.31 km	5.40 km	3.25 km	1.79 km	0.92 km
0.90	2.63	5.92	3.67	2.05	1.08
0.85	2.87	6.30	3.97	2.25	1.20
0.80	3.08	6.60	4.23	2.42	1.29
0.75	3.27	6.85	4.46	2.57	1.39
0.70	3.45	7.08	4.66	2.72	1.47
0.65	3.61	7.30	4.86	2.86	1.56
0.60	3.78	7.52	5.06	3.00	1.64
0.55	3.95	7.71	5.26	3.15	1.73
0.50	4.13	7.90	5.47	3.31	1.82
0.45	4.32	8.10	5.67	3.47	1.93
0.40	4.52	8.32	5.89	3.64	2.04
0.35	4.73	8.55	6.13	3.83	2.16
0.30	4.97	8.78	6.39	4.05	2.31
0.25	5.25	9.03	6.69	4.31	2.48
0.20	5.59	9.34	7.02	4.61	2.69
0.15	6.00	9.71	7.45	5.00	2.96
0.10	6.60	10.17	8.00	5.57	3.39
0.05	7.57	10.92	8.91	6.54	4.17

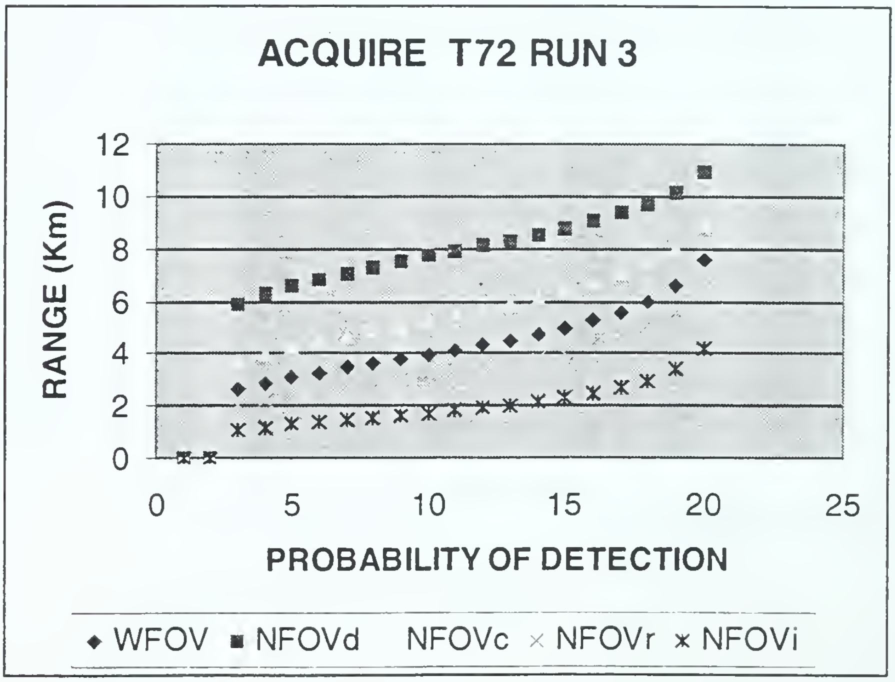


Figure B.3. Range Performance T72. Run 3 (Excel sheet)

```
MESSAGES


      No change in system demand function
      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 11.8 km, extend
      curve to lower frequencies and temperatures.



SENSOR
      gen2 from sensor.dat

TARGET

      T72 S aspect (3.6 meters)
      inherent signature: 1.25 degrees C



OBSERVER ENSEMBLE PERFORMANCE

RANGE GIVEN PROBABILITY...
                WFOV          NFOV          NFOV          NFOV          NFOV
   prob       N50=0.75      N50=0.75      N50=1.50      N50=3.00      N50=6.00
  ------     ----------    ----------    ----------    ----------    ----------
   0.95        3.09 km       6.62 km       4.24 km       2.43 km       1.29 km
   0.90        3.50          7.15          4.73          2.76          1.49
   0.85        3.79          7.53          5.07          3.01          1.65
   0.80        4.04          7.81          5.37          3.23          1.78
   0.75        4.26          8.05          5.62          3.42          1.89
   0.70        4.47          8.27          5.84          3.60          2.01
   0.65        4.66          8.48          6.05          3.77          2.12
   0.60        4.86          8.68          6.27          3.94          2.23
   0.55        5.05          8.86          6.48          4.12          2.35
   0.50        5.25          9.04          6.69          4.31          2.48
   0.45        5.47          9.22          6.89          4.50          2.60
   0.40        5.68          9.42          7.11          4.70          2.74
   0.35        5.91          9.63          7.36          4.91          2.90
   0.30        6.17          9.85          7.62          5.16          3.08
   0.25        6.47         10.08          7.89          5.45          3.30
   0.20        6.81         10.35          8.21          5.78          3.56
   0.15        7.23         10.69          8.63          6.21          3.90
   0.10        7.80         11.11          9.13          6.79          4.40
   0.05        8.72          0.00          9.96          7.76          5.31


end of run 4 from NACIT11
```

RUN # 4
SENSOR: GEN 2

T-72 SIDE ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	3.09 km	6.62 km	4.24 km	2.43 km	1.29 km
0.90	3.50	7.15	4.73	2.76	1.49
0.85	3.79	7.53	5.07	3.01	1.65
0.80	4.04	7.81	5.37	3.23	1.78
0.75	4.26	8.05	5.62	3.42	1.89
0.70	4.47	8.27	5.84	3.60	2.01
0.65	4.66	8.48	6.05	3.77	2.12
0.60	4.86	8.68	6.27	3.94	2.23
0.55	5.05	8.86	6.48	4.12	2.35
0.50	5.25	9.04	6.69	4.31	2.48
0.45	5.47	9.22	6.89	4.50	2.60
0.40	5.68	9.42	7.11	4.70	2.74
0.35	5.91	9.63	7.36	4.91	2.90
0.30	6.17	9.85	7.62	5.16	3.08
0.25	6.47	10.08	7.89	5.45	3.30
0.20	6.81	10.35	8.21	5.78	3.56
0.15	7.23	10.69	8.63	6.21	3.90
0.10	7.80	11.11	9.13	6.79	4.40
0.05	8.72	0.00	9.96	7.76	5.31

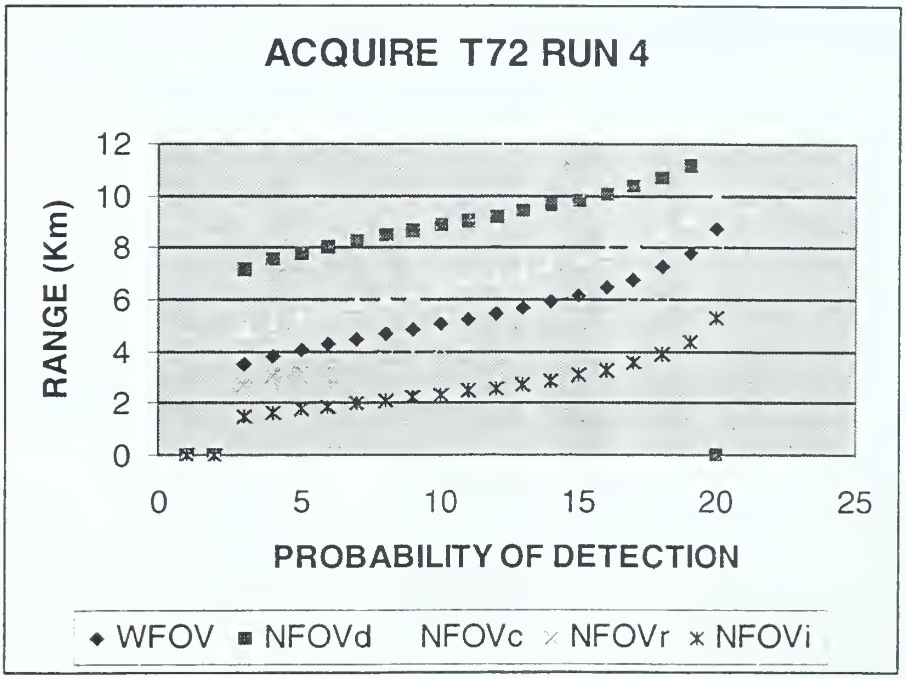


Figure B.4. Range Performance T72. Run 4 (excel sheet)

```
                              Wed Aug 19 15:45:26 1998


run #5
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)
data file: nacit22
command line:  -d nacit22

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

NACIT22: DATA INPUT FOR ACQUIRE:TARGET GUNBOAT NAVY MARITIME CONDITIONS
      >sensor_lookup
                data_file_name             sensor.dat   ---
                sensor_id                  gen1         ---
                performance_mode           MRT        MRT_MDT_MRC_OR_MDC

        >target
                characteristic_size             10.12   meters
                delta_T                         4.6     degrees_C


        >cycle_criteria
                detection_n50                  0.75     wfov
                detection_n50                  0.75     nfov
                classification_n50             1.5      nfov
                recognition_n50                3.0      nfov
                identification_n50             6.0      nfov

        >band-averaged_atmosphere
                #_points: 20    km.............transmittance
                                0.000e+00     1.000e+00
                                5.000e-01     7.951e-01
                                7.500e-01     7.172e-01
                                1.000e+00     6.482e-01
                                2.000e+00     4.381e-01
                                3.000e+00     2.991e-01
                                4.000e+00     2.054e-01
                                5.000e+00     1.417e-01
                                6.000e+00     0.980e-01
                                8.000e+00     0.472e-01
                                1.000e+01     0.229e-01
                                1.200e+01     0.111e-01
                                1.400e+01     0.054e-01
                                1.600e+01     0.027e-02
                                1.800e+01     0.013e-02
                                2.000e+01     0.006e-02
                                2.200e+01     0.003e-02
                                2.400e+01     0.002e-02
                                2.600e+01     0.001e-02
                                2.800e+01     0.000e-02
        >repeat

end parameter listing...
```

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad       MRTD
                2.970e-001     1.020e-002
                4.300e-001     1.460e-002
                5.990e-001     2.100e-002
                8.200e-001     3.020e-002
                1.091e+000     4.340e-002
                1.390e+000     6.230e-002
                1.692e+000     8.960e-002
                1.987e+000     1.288e-001
                2.265e+000     1.851e-001
                2.522e+000     2.660e-001
                2.754e+000     3.823e-001
                2.959e+000     5.494e-001
                3.148e+000     7.896e-001
                3.300e+000     1.135e+000
                3.440e+000     1.631e+000
                3.567e+000     2.344e+000
                3.649e+000     3.369e+000
                3.723e+000     4.841e+000
                3.778e+000     6.958e+000
                3.834e+000     1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 15 km, extend
      curve to lower frequencies and temperatures.



SENSOR
      gen1 from sensor.dat


TARGET
      characteristic dimension: 10.12 meters
      inherent signature: 4.6 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                WFOV         NFOV         NFOV         NFOV         NFOV
   prob       N50=0.75     N50=0.75     N50=1.50     N50=3.00     N50=6.00
  ------     ----------   ----------   ----------   ----------   ----------
   0.95         6.18 km     10.66 km      7.90 km      5.02 km      2.81 km
   0.90         6.82        11.20         8.57         5.63         3.22
   0.85         7.28        11.54         8.99         6.05         3.52
   0.80         7.63        11.80         9.34         6.41         3.78
   0.75         7.93        12.03         9.62         6.70         4.01
   0.70         8.22        12.24         9.86         6.98         4.24
   0.65         8.49        12.45        10.10         7.25         4.46
   0.60         8.72        12.63        10.33         7.51         4.67
   0.55         8.95        12.80        10.54         7.74         4.88
   0.50         9.20        12.97        10.74         7.99         5.10
   0.45         9.45        13.15        10.94         8.26         5.34
   0.40         9.69        13.33        11.16         8.53         5.58
   0.35         9.94        13.52        11.40         8.79         5.85
   0.30        10.22        13.70        11.62         9.09         6.15
   0.25        10.53        13.88        11.88         9.44         6.51
   0.20        10.85        14.07        12.19         9.80         6.91
   0.15        11.27        14.27        12.58        10.26         7.44
   0.10        11.79        14.51        13.07        10.84         8.12
   0.05        12.67        14.82        13.79        11.75         9.27

end of run 5 from nacit22



                                                Wed Aug 19 15:45:26 1998

run #6
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: nacit22
command line:  -d nacit22

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

      >sensor_lookup
                data_file_name               sensor.dat   ---
                sensor_id                    gen2         ---
                performance_mode             MRT        MRT_MDT_MRC_OR_MDC

        >end

end parameter listing...
```

RUN # 5
SENSOR:GEN 1

GUNBOAT FRONT ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	6.18 km	10.66 km	7.90 km	5.02 km	2.81 km
0.90	6.82	11.20	8.57	5.63	3.22
0.85	7.28	11.54	8.99	6.05	3.52
0.80	7.63	11.80	9.34	6.41	3.78
0.75	7.93	12.03	9.62	6.70	4.01
0.70	8.22	12.24	9.86	6.98	4.24
0.65	8.49	12.45	10.10	7.25	4.46
0.60	8.72	12.63	10.33	7.51	4.67
0.55	8.95	12.80	10.54	7.74	4.88
0.50	9.20	12.97	10.74	7.99	5.10
0.45	9.45	13.15	10.94	8.26	5.34
0.40	9.69	13.33	11.16	8.53	5.58
0.35	9.94	13.52	11.40	8.79	5.85
0.30	10.22	13.70	11.62	9.09	6.15
0.25	10.53	13.88	11.88	9.44	6.51
0.20	10.85	14.07	12.19	9.80	6.91
0.15	11.27	14.27	12.58	10.26	7.44
0.10	11.79	14.51	13.07	10.84	8.12
0.05	12.67	14.82	13.79	11.75	9.27

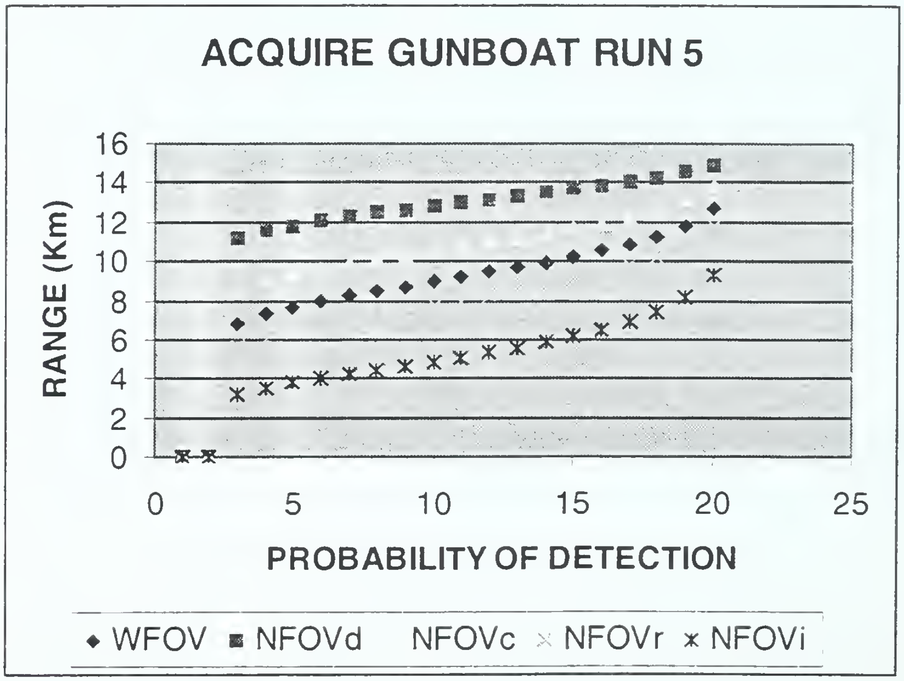


Figure B.5. Range Performance Gunboat. Run 5 (Excel sheet)

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad        MRTD
                9.040e-001     4.090e-002
                1.254e+000     5.460e-002
                1.640e+000     7.300e-002
                2.054e+000     9.750e-002
                2.466e+000     1.302e-001
                2.855e+000     1.739e-001
                3.216e+000     2.323e-001
                3.548e+000     3.102e-001
                3.853e+000     4.143e-001
                4.129e+000     5.534e-001
                4.383e+000     7.392e-001
                4.613e+000     9.873e-001
                4.828e+000     1.319e+000
                5.015e+000     1.761e+000
                5.192e+000     2.352e+000
                5.347e+000     3.142e+000
                5.483e+000     4.197e+000
                5.611e+000     5.605e+000
                5.722e+000     7.487e+000
                5.807e+000     1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 12.6 km, extend
      curve to lower frequencies and temperatures.


SENSOR
      gen2 from sensor.dat


TARGET
      characteristic dimension: 10.12 meters
      inherent signature: 4.6 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
              WFOV        NFOV        NFOV        NFOV        NFOV
    prob     N50=0.75   N50=0.75    N50=1.50    N50=3.00    N50=6.00
   ------   ----------  ----------  ----------  ----------  ----------
    0.95      7.42 km    10.96 km     8.91 km     6.30 km     3.82 km
    0.90      8.01       11.32        9.44        6.91        4.31
    0.85      8.39       11.57        9.75        7.30        4.67
    0.80      8.69       11.77       10.00        7.63        4.96
    0.75      8.93       11.93       10.22        7.90        5.23
    0.70      9.16       12.07       10.39        8.14        5.48
    0.65      9.37       12.20       10.55        8.37        5.70
    0.60      9.55       12.33       10.70        8.59        5.93
    0.55      9.73       12.46       10.86        8.79        6.16
    0.50      9.90       12.59       11.01        8.98        6.38
    0.45     10.09        0.00       11.15        9.19        6.61
    0.40     10.27        0.00       11.30        9.41        6.86
    0.35     10.44        0.00       11.46        9.60        7.13
    0.30     10.63        0.00       11.63        9.82        7.40
    0.25     10.85        0.00       11.83       10.08        7.73
    0.20     11.10        0.00       12.04       10.35        8.08
    0.15     11.38        0.00       12.30       10.66        8.53
    0.10     11.77        0.00        0.00       11.09        9.09
    0.05     12.36        0.00        0.00       11.73        9.95


end of run 6 from nacit22
```

RUN # 6
SENSOR: GEN 2

GUNBOAT FRONT ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	7.42 km	10.96 km	8.91 km	6.30 km	3.82 km
0.90	8.01	11.32	9.44	6.91	4.31
0.85	8.39	11.57	9.75	7.30	4.67
0.80	8.69	11.77	10.00	7.63	4.96
0.75	8.93	11.93	10.22	7.90	5.23
0.70	9.16	12.07	10.39	8.14	5.48
0.65	9.37	12.20	10.55	8.37	5.70
0.60	9.55	12.33	10.70	8.59	5.93
0.55	9.73	12.46	10.86	8.79	6.16
0.50	9.90	12.59	11.01	8.98	6.38
0.45	10.09	0.00	11.15	9.19	6.61
0.40	10.27	0.00	11.30	9.41	6.86
0.35	10.44	0.00	11.46	9.60	7.13
0.30	10.63	0.00	11.63	9.82	7.40
0.25	10.85	0.00	11.83	10.08	7.73
0.20	11.10	0.00	12.04	10.35	8.08
0.15	11.38	0.00	12.30	10.66	8.53
0.10	11.77	0.00	0.00	11.09	9.09
0.05	12.36	0.00	0.00	11.73	9.95

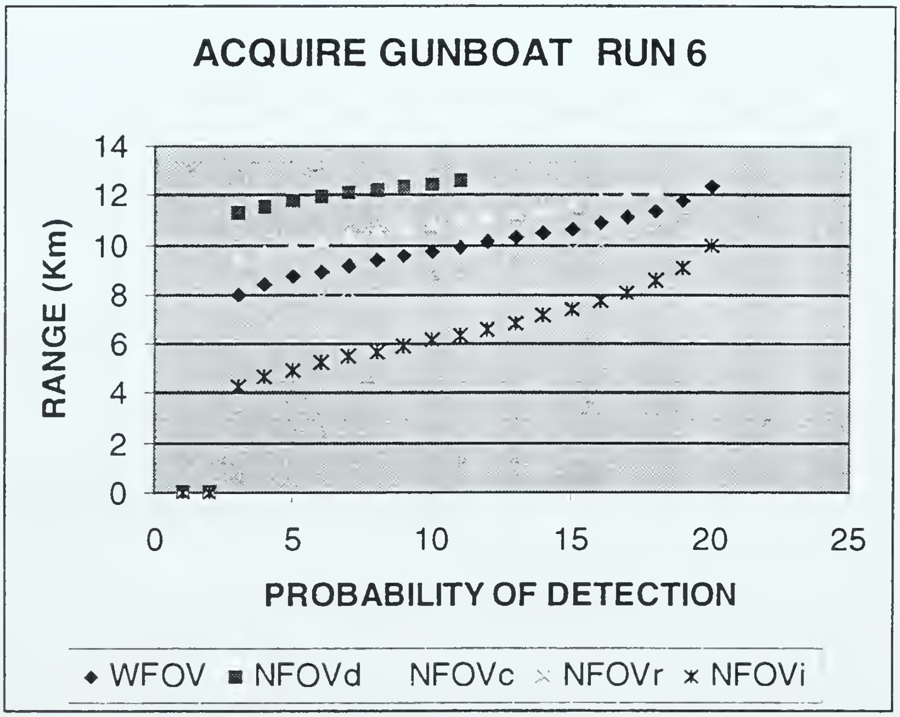


Figure B.6. Range Performance Gunboat. Run 6 (Excel sheet)

```
                                                 Sun Aug  9 15:22:40 1998

run #7
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: NACIT21
command line:  -d NACIT21
TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

NACIT21: DATA INPUT FOR ACQUIRE:TARGET GUNBOAT NAVY MARITIME CONDITIONS
      >sensor_lookup
                data_file_name              sensor.dat   ---
                sensor_id                   gen1         ---
                performance_mode            MRT        MRT_MDT_MRC_OR_MDC

        >target
                characteristic_size              19.6    meters
                delta_T                          4.6     degrees_C


        >cycle_criteria
                detection_n50                   0.75     wfov
                detection_n50                   0.75     nfov
                classification_n50              1.5      nfov
                recognition_n50                 3.0      nfov
                identification_n50              6.0      nfov

        >band-averaged_atmosphere
                #_points: 20    km.............transmittance
                                0.000e+00      1.000e+00
                                5.000e-01      7.951e-01
                                7.500e-01      7.172e-01
                                1.000e+00      6.482e-01
                                2.000e+00      4.381e-01
                                3.000e+00      2.991e-01
                                4.000e+00      2.054e-01
                                5.000e+00      1.417e-01
                                6.000e+00      0.980e-01
                                8.000e+00      0.472e-01
                                1.000e+01      0.229e-01
                                1.200e+01      0.111e-01
                                1.400e+01      0.054e-01
                                1.600e+01      0.027e-02
                                1.800e+01      0.013e-02
                                2.000e+01      0.006e-02
                                2.200e+01      0.003e-02
                                2.400e+01      0.002e-02
                                2.600e+01      0.001e-02
                                2.800e+01      0.000e-02
        >repeat

end parameter listing...
```

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad        MRTD
                2.970e-001      1.020e-002
                4.300e-001      1.460e-002
                5.990e-001      2.100e-002
                8.200e-001      3.020e-002
                1.091e+000      4.340e-002
                1.390e+000      6.230e-002
                1.692e+000      8.960e-002
                1.987e+000      1.288e-001
                2.265e+000      1.851e-001
                2.522e+000      2.660e-001
                2.754e+000      3.823e-001
                2.959e+000      5.494e-001
                3.148e+000      7.896e-001
                3.300e+000      1.135e+000
                3.440e+000      1.631e+000
                3.567e+000      2.344e+000
                3.649e+000      3.369e+000
                3.723e+000      4.841e+000
                3.778e+000      6.958e+000
                3.834e+000      1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 15 km, extend
      curve to lower frequencies and temperatures.


SENSOR

      gen1 from sensor.dat


TARGET

      characteristic dimension: 19.6 meters
      inherent signature: 4.6 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                WFOV         NFOV         NFOV         NFOV         NFOV
   prob      N50=0.75     N50=0.75     N50=1.50     N50=3.00     N50=6.00
  ------    ----------   ----------   ----------   ----------   ----------
   0.95       8.98 km     12.82 km     10.56 km      7.77 km      4.89 km
   0.90       9.61        13.27        11.08         8.44         5.50
   0.85      10.00        13.56        11.45         8.85         5.91
   0.80      10.32        13.75        11.70         9.20         6.27
   0.75      10.58        13.90        11.92         9.50         6.57
   0.70      10.80        14.03        12.13         9.74         6.84
   0.65      11.01        14.14        12.34         9.97         7.10
   0.60      11.22        14.24        12.53        10.20         7.37
   0.55      11.43        14.33        12.71        10.43         7.61
   0.50      11.60        14.42        12.88        10.63         7.85
   0.45      11.79        14.50        13.06        10.83         8.11
   0.40      11.98        14.58        13.24        11.04         8.40
   0.35      12.20        14.66        13.43        11.28         8.66
   0.30      12.45        14.75        13.62        11.53         8.96
   0.25      12.70        14.83        13.81        11.78         9.31
   0.20      12.98        14.92        14.00        12.08         9.68
   0.15      13.33         0.00        14.22        12.48        10.14
   0.10      13.75         0.00        14.47        12.97        10.73
   0.05      14.27         0.00        14.79        13.72        11.65


end of run 7 from NACIT21




                                                        Sun Aug  9 15:22:41 1998

run #8
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: NACIT21
command line:  -d NACIT21
TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

      >sensor_lookup
                data_file_name             sensor.dat    ---
                sensor_id                  gen2          ---
                performance_mode           MRT        MRT_MDT_MRC_OR_MDC


        >end


end parameter listing...
```

RUN # 7
SENSOR: GEN 1

GUNBOAT SIDE ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	8.98 km	12.82 km	10.56 km	7.77 km	4.89 km
0.90	9.61	13.27	11.08	8.44	5.50
0.85	10.00	13.56	11.45	8.85	5.91
0.80	10.32	13.75	11.70	9.20	6.27
0.75	10.58	13.90	11.92	9.50	6.57
0.70	10.80	14.03	12.13	9.74	6.84
0.65	11.01	14.14	12.34	9.97	7.10
0.60	11.22	14.24	12.53	10.20	7.37
0.55	11.43	14.33	12.71	10.43	7.61
0.50	11.60	14.42	12.88	10.63	7.85
0.45	11.79	14.50	13.06	10.83	8.11
0.40	11.98	14.58	13.24	11.04	8.40
0.35	12.20	14.66	13.43	11.28	8.66
0.30	12.45	14.75	13.62	11.53	8.96
0.25	12.70	14.83	13.81	11.78	9.31
0.20	12.98	14.92	14.00	12.08	9.68
0.15	13.33	0.00	14.22	12.48	10.14
0.10	13.75	0.00	14.47	12.97	10.73
0.05	14.27	0.00	14.79	13.72	11.65

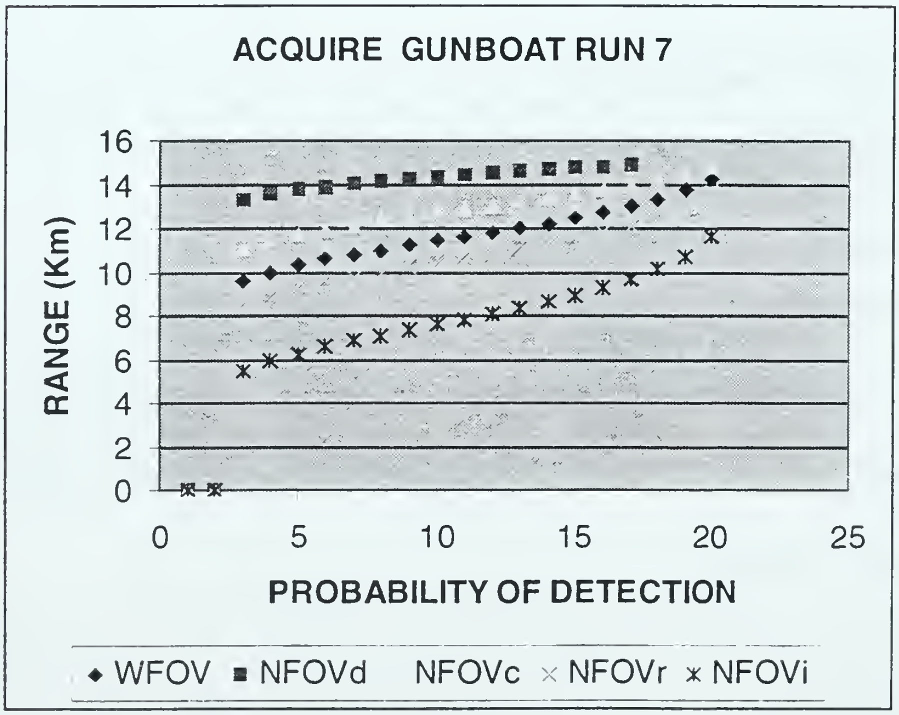


Figure B.7. Range Performance Gunboat. Run 7 (excel sheet)

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad       MRTD
                9.040e-001     4.090e-002
                1.254e+000     5.460e-002
                1.640e+000     7.300e-002
                2.054e+000     9.750e-002
                2.466e+000     1.302e-001
                2.855e+000     1.739e-001
                3.216e+000     2.323e-001
                3.548e+000     3.102e-001
                3.853e+000     4.143e-001
                4.129e+000     5.534e-001
                4.383e+000     7.392e-001
                4.613e+000     9.873e-001
                4.828e+000     1.319e+000
                5.015e+000     1.761e+000
                5.192e+000     2.352e+000
                5.347e+000     3.142e+000
                5.483e+000     4.197e+000
                5.611e+000     5.605e+000
                5.722e+000     7.487e+000
                5.807e+000     1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 12.6 km, extend
      curve to lower frequencies and temperatures.


SENSOR

      gen2 from sensor.dat

TARGET

      characteristic dimension: 19.6 meters
      inherent signature: 4.6 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                WFOV          NFOV          NFOV          NFOV          NFOV
    prob      N50=0.75      N50=0.75      N50=1.50      N50=3.00      N50=6.00
   ------    ----------    ----------    ----------    ----------    ----------
    0.95        9.74 km      12.47 km      10.87 km       8.81 km       6.19 km
    0.90       10.21          0.00         11.24          9.33          6.78
    0.85       10.48          0.00         11.49          9.65          7.18
    0.80       10.70          0.00         11.69          9.90          7.50
    0.75       10.89          0.00         11.86         10.12          7.79
    0.70       11.06          0.00         12.00         10.30          8.02
    0.65       11.20          0.00         12.13         10.46          8.25
    0.60       11.34          0.00         12.26         10.62          8.47
    0.55       11.48          0.00         12.39         10.77          8.68
    0.50       11.62          0.00         12.52         10.93          8.87
    0.45       11.76          0.00          0.00         11.08          9.08
    0.40       11.90          0.00          0.00         11.22          9.30
    0.35       12.05          0.00          0.00         11.38          9.51
    0.30       12.20          0.00          0.00         11.56          9.73
    0.25       12.38          0.00          0.00         11.76          9.98
    0.20       12.59          0.00          0.00         11.97         10.27
    0.15        0.00          0.00          0.00         12.23         10.57
    0.10        0.00          0.00          0.00         12.59         11.01
    0.05        0.00          0.00          0.00          0.00         11.65


end of run 8 from NACIT21
```

SENSOR: GEN 2

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	9.74	12.47	10.87	8.81	6.19
0.90	10.21	0.00	11.24	9.33	6.78
0.85	10.48	0.00	11.49	9.65	7.18
0.80	10.70	0.00	11.69	9.90	7.50
0.75	10.89	0.00	11.86	10.12	7.79
0.70	11.06	0.00	12.00	10.30	8.02
0.65	11.20	0.00	12.13	10.46	8.25
0.60	11.34	0.00	12.26	10.62	8.47
0.55	11.48	0.00	12.39	10.77	8.68
0.50	11.62	0.00	12.52	10.93	8.87
0.45	11.76	0.00	0.00	11.08	9.08
0.40	11.90	0.00	0.00	11.22	9.30
0.35	12.05	0.00	0.00	11.38	9.51
0.30	12.20	0.00	0.00	11.56	9.73
0.25	12.38	0.00	0.00	11.76	9.98
0.20	12.59	0.00	0.00	11.97	10.27
0.15	0.00	0.00	0.00	12.23	10.57
0.10	0.00	0.00	0.00	12.59	11.01
0.05	0.00	0.00	0.00	0.00	11.65

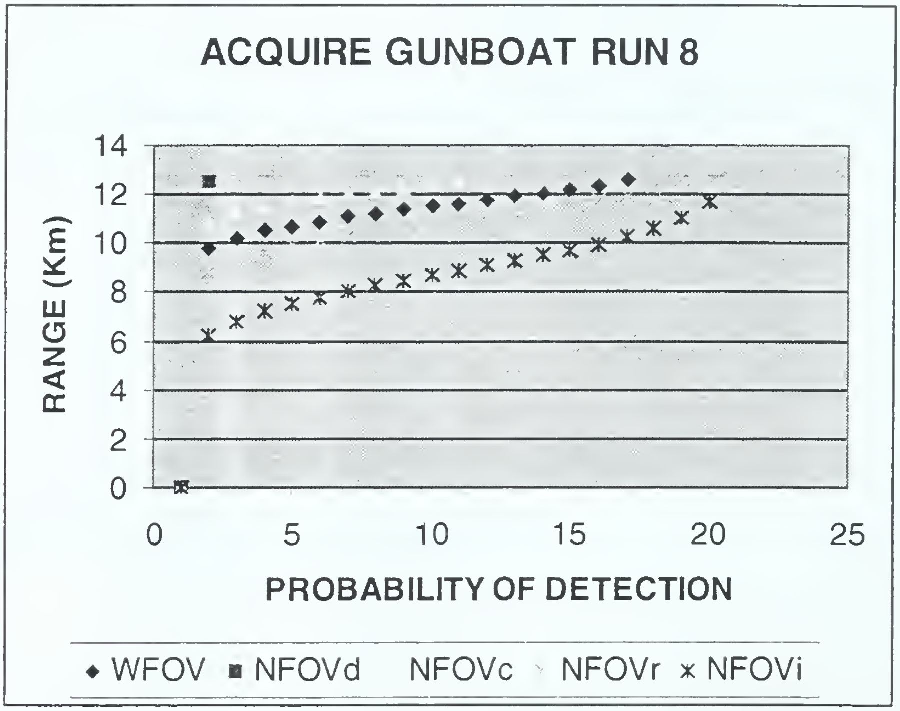


Figure B.8. Range Performance Gunboat. Run 8 (Excel sheet)

```
                                                   Mon Sep 14 10:01:28 1998

run #9
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: nacit232
command line:  -d nacit232

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

NACIT22: DATA INPUT FOR ACQUIRE:TARGET GUNBOAT NAVY MARITIME CONDITIONS
      >sensor_lookup
                data_file_name             sensor.dat   ---
                sensor_id                  nacit9       ---
                performance_mode           MRT        MRT_MDT_MRC_OR_MDC

        >target
                characteristic_size             10.12   meters
                delta_T                         4.6     degrees_C


        >cycle_criteria
                detection_n50                  0.75     wfov
                detection_n50                  0.75     nfov
                classification_n50             1.5      nfov
                recognition_n50                3.0      nfov
                identification_n50             6.0      nfov

        >band-averaged_atmosphere
                #_points: 20    km.............transmittance
                                0.000e+00     1.000e+00
                                5.000e-01     7.951e-01
                                7.500e-01     7.172e-01
                                1.000e+00     6.482e-01
                                2.000e+00     4.381e-01
                                3.000e+00     2.991e-01
                                4.000e+00     2.054e-01
                                5.000e+00     1.417e-01
                                6.000e+00     0.980e-01
                                8.000e+00     0.472e-01
                                1.000e+01     0.229e-01
                                1.200e+01     0.111e-01
                                1.400e+01     0.054e-01
                                1.600e+01     0.027e-02
                                1.800e+01     0.013e-02
                                2.000e+01     0.006e-02
                                2.200e+01     0.003e-02
                                2.400e+01     0.002e-02
                                2.600e+01     0.001e-02
                                2.800e+01     0.000e-02

>repeat

end parameter listing...
```

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad       MRTD
                2.510e-001     1.080e-002
                3.120e-001     1.310e-002
                3.720e-001     1.590e-002
                4.330e-001     1.940e-002
                4.940e-001     2.350e-002
                5.770e-001     2.860e-002
                6.630e-001     3.470e-002
                7.490e-001     4.220e-002
                8.440e-001     5.130e-002
                9.400e-001     6.230e-002
                1.036e+000     7.570e-002
                1.130e+000     9.200e-002
                1.225e+000     1.118e-001
                1.318e+000     1.359e-001
                1.408e+000     1.652e-001
                1.488e+000     2.007e-001
                1.562e+000     2.439e-001
                1.614e+000     2.964e-001
                1.647e+000     3.601e-001
                1.680e+000     4.376e-001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline intersects MRTD/MRC cutoff below range 6 km.


SENSOR

      nacit9 from sensor.dat


TARGET

      characteristic dimension: 10.12 meters
      inherent signature: 4.6 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                WFOV         NFOV         NFOV         NFOV         NFOV
   prob       N50=0.75     N50=0.75     N50=1.50     N50=3.00     N50=6.00
  ------     ----------   ----------   ----------   ----------   ----------
   0.95        3.70 km      9.01 km      5.55 km      2.78 km      1.39 km
   0.90        4.31         9.66         6.40         3.24         1.62
   0.85        4.79        10.08         6.95         3.59         1.80
   0.80        5.20        10.42         7.38         3.90         1.95
   0.75        5.59        10.69         7.74         4.19         2.10
   0.70        5.97        10.94         8.04         4.47         2.24
   0.65        6.29        11.16         8.33         4.76         2.38
   0.60        6.60        11.39         8.59         5.05         2.52
   0.55        6.91        11.59         8.85         5.35         2.68
   0.50        7.22        11.80         9.10         5.67         2.84
   0.45        7.53        12.02         9.36         6.01         3.01
   0.40        7.83        12.23         9.61         6.34         3.20
   0.35        8.14        12.47         9.89         6.69         3.42
   0.30        8.47        12.73        10.18         7.08         3.68
   0.25        8.84        13.02        10.51         7.51         4.00
   0.20        9.25        13.34        10.88         7.97         4.40
   0.15        9.75        13.68        11.32         8.52         4.96
   0.10       10.41        14.05        11.91         9.23         5.84
   0.05       11.43        14.56        12.87        10.35         7.30

end of run 9 from nacit232
```

```
                              Mon Sep 14 10:01:28 1998
run #10
U.S. Army CECOM RDEC NVESD
ACQUIRE version 1 (May 30 1995)

data file: nacit232
command line:  -d nacit232

TARGET DISCRIMINATION RANGE PERFORMANCE

begin parameter listing...

      >sensor_lookup
                data_file_name             sensor.dat    ---
                sensor_id                  gen2          ---
                performance_mode           MRT        MRT_MDT_MRC_OR_MDC

        >end

end parameter listing...
```

GUNBOAT FRONT ASPECT

SENSOR: NACIT9

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	3.70	9.01	5.55	2.78	1.39
0.90	4.31	9.66	6.40	3.24	1.62
0.85	4.79	10.08	6.95	3.59	1.80
0.80	5.20	10.42	7.38	3.90	1.95
0.75	5.59	10.69	7.74	4.19	2.10
0.70	5.97	10.94	8.04	4.47	2.24
0.65	6.28	11.16	8.33	4.76	2.38
0.60	6.60	11.39	8.59	5.05	2.52
0.55	6.91	11.59	8.85	5.35	2.68
0.50	7.22	11.80	9.10	5.64	2.84
0.45	7.53	12.02	9.36	6.01	3.01
0.40	7.82	12.23	9.61	6.34	3.20
0.35	8.14	12.47	9.89	6.69	3.42
0.30	8.47	12.73	10.18	7.08	3.68
0.25	8.84	13.02	10.51	7.51	4.00
0.20	9.25	13.34	10.88	7.98	4.40
0.15	9.75	13.68	11.32	8.52	4.96
0.10	10.41	14.05	11.91	9.23	5.84
0.05	11.43	14.56	12.87	10.35	7.30

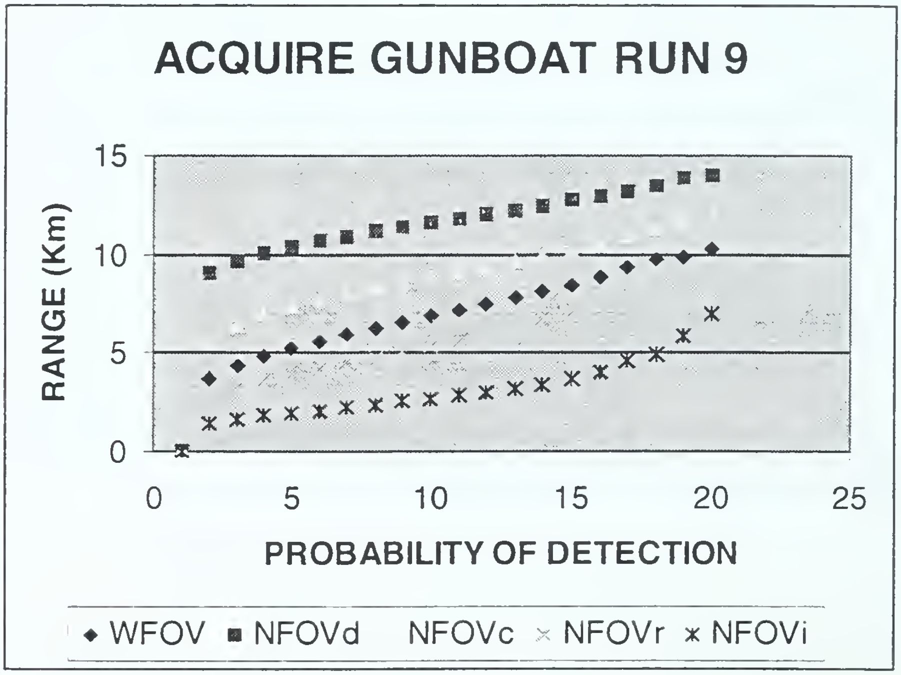


Figure B.9. Range Performance Gunboat. Run 9 (excel sheet)

```
MESSAGES

        2D MRTD from lookup table

                cyles/mrad        MRTD
                9.040e-001     4.090e-002
                1.254e+000     5.460e-002
                1.640e+000     7.300e-002
                2.054e+000     9.750e-002
                2.466e+000     1.302e-001
                2.855e+000     1.739e-001
                3.216e+000     2.323e-001
                3.548e+000     3.102e-001
                3.853e+000     4.143e-001
                4.129e+000     5.534e-001
                4.383e+000     7.392e-001
                4.613e+000     9.873e-001
                4.828e+000     1.319e+000
                5.015e+000     1.761e+000
                5.192e+000     2.352e+000
                5.347e+000     3.142e+000
                5.483e+000     4.197e+000
                5.611e+000     5.605e+000
                5.722e+000     7.487e+000
                5.807e+000     1.000e+001


      Sky-to-ground ratio defaulted to 1 for thermal systems.
      Last range for input atmospheric transmittance data is less
      than maximum range.
      Spline fit returned a negative atmospheric transmittance; add
      more points to input transmittance data array.
      Loadline does not intersect MRTD/MRC above range 12.6 km, extend
      curve to lower frequencies and temperatures.


SENSOR

      gen2 from sensor.dat


TARGET

      characteristic dimension: 10.12 meters
      inherent signature: 4.6 degrees C
```

```
OBSERVER ENSEMBLE PERFORMANCE
RANGE GIVEN PROBABILITY...
                WFOV         NFOV         NFOV         NFOV         NFOV
   prob       N50=0.75     N50=0.75     N50=1.50     N50=3.00     N50=6.00
  ------     ----------   ----------   ----------   ----------   ----------
   0.95         7.42 km     10.96 km      8.91 km      6.30 km      3.82 km
   0.90         8.01        11.32         9.44         6.91         4.31
   0.85         8.39        11.57         9.75         7.30         4.67
   0.80         8.69        11.77        10.00         7.63         4.96
   0.75         8.93        11.93        10.22         7.90         5.23
   0.70         9.16        12.07        10.39         8.14         5.48
   0.65         9.37        12.20        10.55         8.37         5.70
   0.60         9.55        12.33        10.70         8.59         5.93
   0.55         9.73        12.46        10.86         8.79         6.16
   0.50         9.90        12.59        11.01         8.98         6.38
   0.45        10.09         0.00        11.15         9.19         6.61
   0.40        10.27         0.00        11.30         9.41         6.86
   0.35        10.44         0.00        11.46         9.60         7.13
   0.30        10.63         0.00        11.63         9.82         7.40
   0.25        10.85         0.00        11.83        10.08         7.73
   0.20        11.10         0.00        12.04        10.35         8.08
   0.15        11.38         0.00        12.30        10.66         8.53
   0.10        11.77         0.00         0.00        11.09         9.09
   0.05        12.36         0.00         0.00        11.73         9.95

end of run 10 from nacit232
```

RUN # 10
SENSOR: NACIT9

GUNBOAT FRONT ASPECT

	WFOV	NFOVd	NFOVc	NFOVr	NFOVi
Prob	N50=0.75	N50=0.75	N50=1.5	N50=3.0	N50=6.0
0.95	3.70	9.01	5.55	2.78	1.39
0.90	4.31	9.66	6.40	3.24	1.62
0.85	4.79	10.08	6.95	3.59	1.80
0.80	5.20	10.42	7.38	3.90	1.95
0.75	5.59	10.69	7.74	4.19	2.10
0.70	5.97	10.94	8.04	4.47	2.24
0.65	6.28	11.16	8.33	4.76	2.38
0.60	6.60	11.39	8.59	5.05	2.52
0.55	6.91	11.59	8.85	5.35	2.68
0.50	7.22	11.80	9.10	5.64	2.84
0.45	7.53	12.02	9.36	6.01	3.01
0.40	7.82	12.23	9.61	6.34	3.20
0.35	8.14	12.47	9.89	6.69	3.42
0.30	8.47	12.73	10.18	7.08	3.68
0.25	8.84	12.90	10.51	7.51	4.00
0.20	9.30	13.10	10.88	7.98	4.62
0.15	9.75	13.43	11.32	8.49	4.96
0.10	9.91	13.87	11.56	9.11	5.84
0.05	10.30	14.01	12.24	9.35	6.98

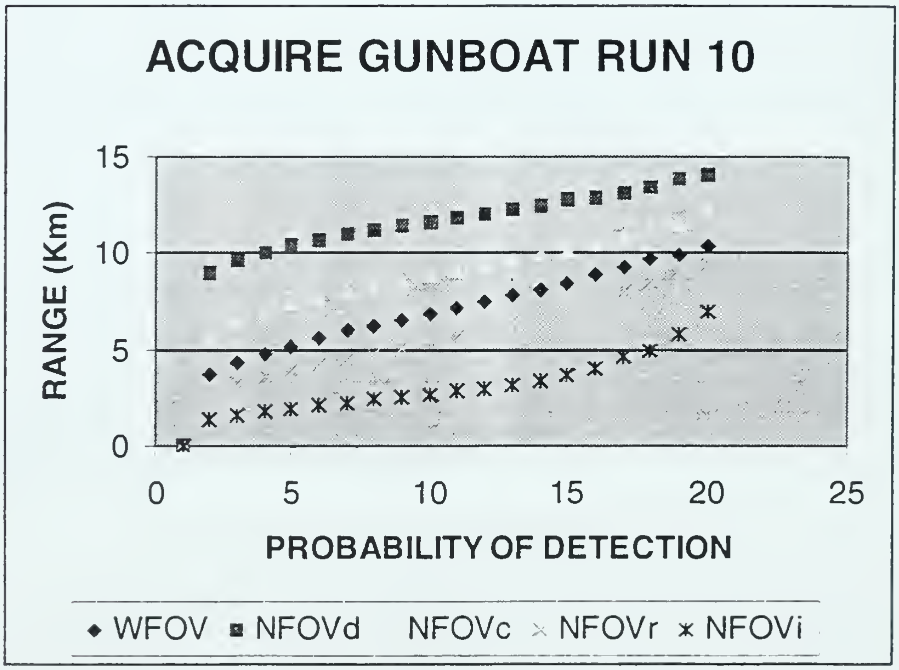
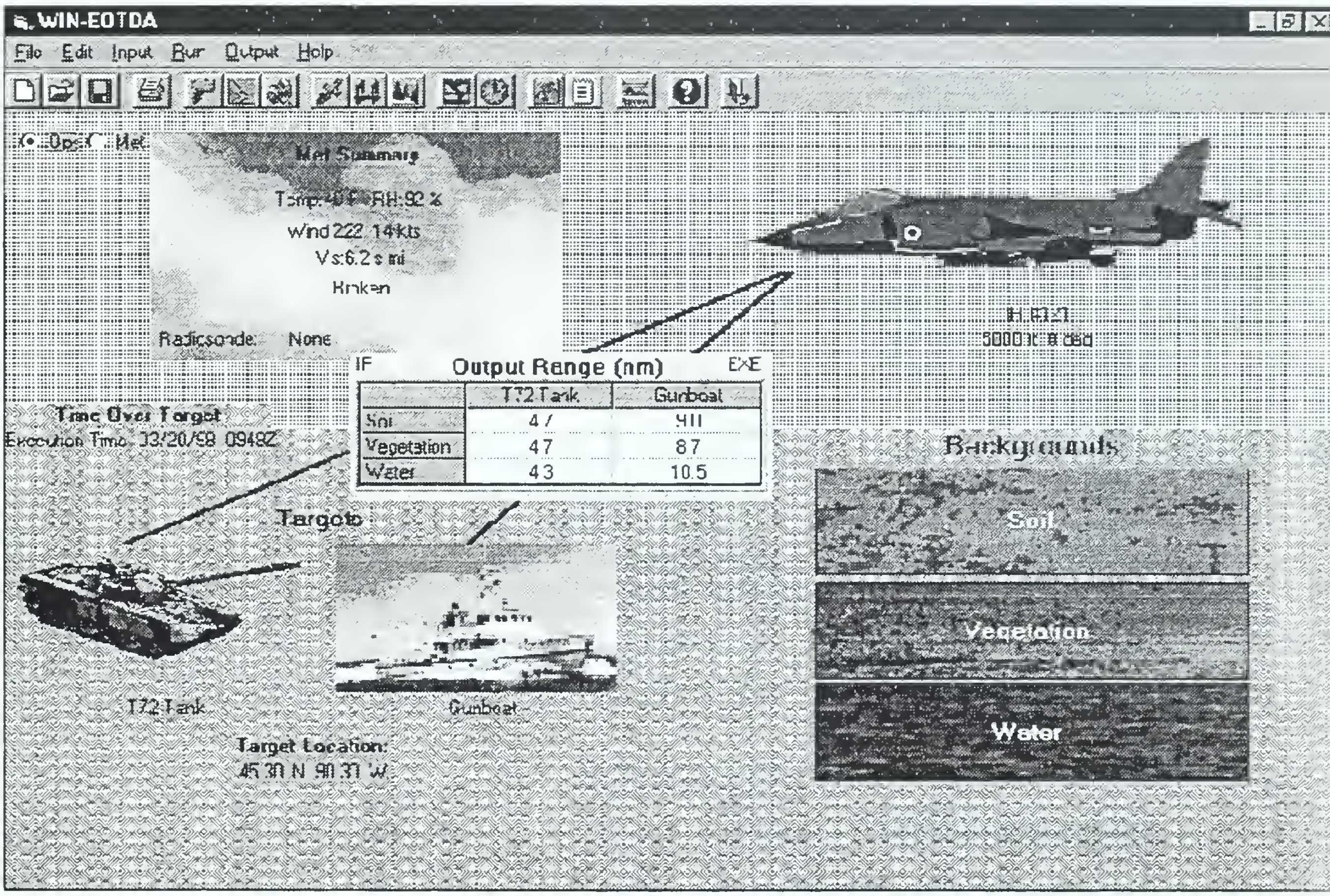


Figure B.10. Range Performance Gunboat. Run 10 (Excel sheet)

APPENDIX C. SAMPLE WINEOTDA



Met Summary

Temp:40 F RH:92 %

Wind 222 14kts

Vs:6.2 s mi

Broken

Radiosonde: None

Time Over Target

Execution Time: 03/20/98 0948Z

Output Range (nm)

IR EXE

	T72 Tank	Gunboat
Soil	47	9.0
Vegetation	47	8.7
Water	43	10.5

Target Location:

45 30 N 90 37 W

Figure C.1. WinEOTDA Main Screen

```
IR EOTDA EXECUTION SUMMARY

==========================================================================

 MET DATA INPUT FILE NAME: C:\PROGRAM FILES\WINEOTDA\met\met0911_.

 OPS DATA INPUT FILE NAME: C:\PROGRAM FILES\WINEOTDA\ops\IR091111.44


TOT: 11 September 1998 1004
 Absolute Humidity: 6.8 (g/m**3)          4 km Transmissivity:0.58
 Sky Temperature: 238.7 (deg K)           IR Visibility: 018.8 (kft)

==========================================================================

 Latitude: 36 deg 46 min N        Longitude: 122 deg 18 min W
 Sensor ID: 151(GEN1)              Sensor Ht: 3,000 feet
 View Direction: 000               Complexity: None

==========================================================================


                  TARGET INFORMATION

 Target Elevation: 0 feet (MSL)

 Target #1                         Target #2
 ---------------------------------   ---------------------------------
 Target ID:      Gunboat                  Target ID: Gunboat
 Target Heading:  0                   Target Heading:  90
 Operating State:  idle               Operating State: exercised
 Target Speed:     0                  Target Speed:  15knots

--------------------------------------------------------------------------



                  BACKGROUND INFORMATION

 General Background Albedo: Continental

 Background #1 ID:   Water (15 f)
 Background #2 ID:   Water (25 f)
 Background #3 ID:   Water (35 f)
==========================================================================
```

IR EOTDA OUTPUT

```
=====================================================================
 RANGES        Target #1 Gunboat  Background #1 Water
View Dir | MRT Detection Range (kft) | MDT Detection Range (kft) | Lock-on Range
 (deg)  |  NFOV         WFOV   |  NFOV         WFOV   |   (kft)
----------|-------------|-------------|-------------|-------------|--------------
  000      99.3       75.9      29.8        24.2       0.0
  045     112.8       88.8      27.9        22.4       0.0
  090     114.0       88.8      20.5        16.2       0.0
  135     112.8       88.8      12.5        16.2       0.0
  180     100.5       77.7      15.6        15.6       0.0
  225     112.8       88.8      11.9        10.1       0.0
  270     114.7       88.8      20.5        16.2       0.0
  315     112.8       88.8      27.9        22.4       0.0

=====================================================================

 THERMAL CONTRAST (Delta-T)  Target #1 Gunboat  Background #1 Water
View Dir |     MRT Delta T (K)     |     MDT Delta T (K)     | Lock-on Delta-T
 (deg)  |  NFOV         WFOV   |  NFOV         WFOV   |
----------|-------------|-------------|-------------|-------------|--------------
  000     09.6      8.8     42.2       14.3      0.0
  045     10.2      9.5     42.0       13.9      0.0
  090     10.4      9.7     32.8       11.0      0.0
  135     10.4      9.7     24.3       07.7      0.0
  180     10.4      9.5     07.1       07.1      0.0
  225     10.3      9.7     22.8       08.6      0.0
  270     10.5      9.8     30.9       10.5      0.0
  315     10.1      9.5     42.0       13.5      0.0

=====================================================================

 TEMPERATURES (K)    Target #1 Gunboat  Background #1 Water
View Dir | Bkgd Temp | MRT Temperature (K) | MDT Temperature (K) | Lock-on Temp
 (deg)  |   (K)    |  NFOV     WFOV    |  NFOV     WFOV    |    (K)
----------|-----------|----------|----------|----------|----------|--------------
  000   269.3     279.2      279.3     316.3      289.2      300.0
  045     0.0     279.5      279.5     316.3      289.3      300.0
  090     0.0     279.7      279.7     308.6      288.1      300.0
  135     0.0     279.7      279.7     302.3      284.8      300.0
  180     0.0     280.0      279.9     284.2      284.2      300.0
  225     0.0     279.7      279.6     300.9      287.7      300.0
  270     0.0     279.8      279.8     306.6      287.6      300.0
  315     0.0     279.5      279.5     316.3      289.0      300.0

=====================================================================
 RANGES        Target #1 Gunboat  Background #2 Water
View Dir | MRT Detection Range (kft) | MDT Detection Range (kft) | Lock-on Range
 (deg)  |  NFOV        WFOV   |  NFOV        WFOV   |   (kft)
----------|-------------|-------------|-------------|-------------|---------------
  000      99.9       75.9      29.8       24.2       0.0
  045     112.8       88.8      27.9       22.4       0.0
  090     114.7       88.8      20.5       16.2       0.0
  135     113.4       88.8      12.5       16.2       0.0
  180     100.5       77.7      16.2       16.2       0.0
  225     113.4       88.8      11.9       10.1       0.0
  270     114.7       88.8      20.5       16.2       0.0
  315     112.8       88.8      27.9       22.4       0.0

==========================================================================

 THERMAL CONTRAST (Delta-T)  Target #1 Gunboat  Background #2 Water
View Dir |    MRT Delta T (K)     |    MDT Delta T (K)     | Lock-on Delta-T
 (deg)  |  NFOV        WFOV   |  NFOV        WFOV   |
----------|-------------|-------------|-------------|-------------|---------------
  000       9.7       8.9     42.3      14.4       0.0
  045      10.3       9.6     42.1      14.0       0.0
  090      10.5       9.8     33.0      11.2       0.0
  135      10.5       9.8     24.4       7.8       0.0
  180      10.4       9.6      7.2       7.2       0.0
  225      10.4       9.8     22.9       8.8       0.0
  270      10.6       9.9     31.0      10.6       0.0
  315      10.2       9.6     42.1      13.7       0.0

==========================================================================

 TEMPERATURES (K)    Target #1 Gunboat  Background #2 Water
View Dir | Bkgd Temp | MRT Temperature (K) | MDT Temperature (K) | Lock-on Temp
 (deg)  |  (K)   |  NFOV     WFOV   |  NFOV     WFOV   |   (K)
----------|-----------|----------|----------|----------|----------|---------------
  000   269.2     279.2       279.3     316.3      289.2      300.0
  045     0.0     279.5       279.5     316.3      289.3      300.0
  090     0.0     279.7       279.7     308.6      288.1      300.0
  135     0.0     279.7       279.7     302.3      284.8      300.0
  180     0.0     280.0       279.9     284.2      284.2      300.0
  225     0.0     279.7       279.6     300.9      287.7      300.0
  270     0.0     279.8       279.8     306.6      287.6      300.0
  315     0.0     279.5       279.5     316.3      289.0      300.0

==========================================================================
RANGES        Target #1 Gunboat  Background #3 Water
View Dir | MRT Detection Range (kft) | MDT Detection Range (kft) | Lock-on Range
 (deg)  |  NFOV          WFOV    |  NFOV          WFOV    |    (kft)
----------|-------------|-------------|-------------|-------------|--------------
  000      99.3       75.9     29.8       24.2       0.0
  045     112.8       88.8     27.9       22.4       0.0
  090     114.0       88.8     20.5       16.2       0.0
  135     112.8       88.8     12.5       16.2       0.0
  180     100.5       77.7     15.6       15.6       0.0
  225     112.8       88.8     11.9       10.1       0.0
  270     114.7       88.8     20.5       16.2       0.0
  315     112.8       88.8     27.9       22.4       0.0

=========================================================================

 THERMAL CONTRAST (Delta-T)  Target #1 Gunboat  Background #3 Water
View Dir |    MRT Delta T (K)     |    MDT Delta T (K)     | Lock-on Delta-T
 (deg)  |  NFOV          WFOV    |  NFOV          WFOV    |
----------|-------------|-------------|-------------|-------------|--------------
  000       9.6       8.8     42.2       14.3       0.0
  045      10.2       9.5     42.0       13.9       0.0
  090      10.4       9.7     32.8       11.0       0.0
  135      10.4       9.7     24.3        7.7       0.0
  180      10.4       9.5      7.1        7.1       0.0
  225      10.3       9.7     22.8        8.6       0.0
  270      10.5       9.8     30.9       10.5       0.0
  315      10.1       9.5     42.0       13.5       0.0

=========================================================================

 TEMPERATURES (K)   Target #1 Gunboat  Background #3 Water
View Dir | Bkgd Temp | MRT Temperature (K) | MDT Temperature (K) | Lock-on Temp
 (deg)  |   (K)    |  NFOV      WFOV    |  NFOV      WFOV    |    (K)
----------|-----------|----------|----------|----------|----------|--------------
  000   269.3   279.2        279.3     316.3       289.2       300.0
  045     0.0   279.5        279.5     316.3       289.3       300.0
  090     0.0   279.7        279.7     308.6       288.1       300.0
  135     0.0   279.7        279.7     302.3       284.8       300.0
  180     0.0   280.0        279.9     284.2       284.2       300.0
  225     0.0   279.7        279.6     300.9       287.7       300.0
  270     0.0   279.8        279.8     306.6       287.6       300.0
  315     0.0   279.5        279.5     316.3       289.0       300.0

              0.0 -> No Value Computed.
             -1.0 -> No Solution Possible.
             -2.0 -> Sensor is Above Overcast.
 RANGES        Target #2 Gunboat  Background #1 Water
View Dir | MRT Detection Range (kft) | MDT Detection Range (kft) | Lock-on Range
 (deg)  |   NFOV         WFOV    |   NFOV        WFOV    |    (kft)
----------|-------------|-------------|-------------|-------------|---------------
  000      99.3        75.9      29.8        24.2        0.0
  045     112.8        88.8      27.9        22.4        0.0
  090     114.0        88.8      20.5        16.2        0.0
  135     112.8        88.8      12.5        16.2        0.0
  180     100.5        77.7      15.6        15.6        0.0
  225     112.8        88.8      11.9        10.1        0.0
  270     114.7        88.8      20.5        16.2        0.0
  315     112.8        88.8      27.9        22.4        0.0

==============================================================================

 THERMAL CONTRAST (Delta-T)  Target #2 Gunboat  Background #1 Water
View Dir |    MRT Delta T (K)     |     MDT Delta T (K)     | Lock-on Delta-T
 (deg)  |   NFOV         WFOV    |   NFOV        WFOV    |
----------|-------------|-------------|-------------|-------------|---------------
  000      9.6        8.8      42.2       14.3       0.0
  045     10.2        9.5      42.0       13.9       0.0
  090     10.4        9.7      32.8       11.0       0.0
  135     10.4        9.7      24.3        7.7       0.0
  180     10.4        9.5       7.1        7.1       0.0
  225     10.3        9.7      22.8        8.6       0.0
  270     10.5        9.8      30.9       10.5       0.0
  315     10.1        9.5      42.0       13.5       0.0

==============================================================================

 TEMPERATURES (K)    Target #2 Gunboat  Background #1 Water
View Dir | Bkgd Temp | MRT Temperature (K) | MDT Temperature (K) | Lock-on Temp
 (deg)  |   (K)    |  NFOV     WFOV    |  NFOV     WFOV    |    (K)
----------|-----------|----------|----------|----------|----------|---------------
  000   269.3   279.2        279.3     316.3        289.2        300.0
  045     0.0   279.5        279.5     316.3        289.3        300.0
  090     0.0   279.7        279.7     308.6        288.1        300.0
  135     0.0   279.7        279.7     302.3        284.8        300.0
  180     0.0   280.0        279.9     284.2        284.2        300.0
  225     0.0   279.7        279.6     300.9        287.7        300.0
  270     0.0   279.8        279.8     306.6        287.6        300.0
  315     0.0   279.5        279.5     316.3        289.0        300.0

==============================================================================
 RANGES        Target #2 Gunboat  Background #2 Water
View Dir | MRT Detection Range (kft) | MDT Detection Range (kft) | Lock-on Range
 (deg)  |   NFOV        WFOV   |   NFOV        WFOV   |    (kft)
----------|-------------|-------------|-------------|-------------|--------------
  000       99.9        75.9       29.8        24.2        0.0
  045      112.8        88.8       27.9        22.4        0.0
  090      114.7        88.8       20.5        16.2        0.0
  135      113.4        88.8       12.5        16.2        0.0
  180      100.5        77.7       16.2        16.2        0.0
  225      113.4        88.8       11.9        10.1        0.0
  270      114.7        88.8       20.5        16.2        0.0
  315      112.8        88.8       27.9        22.4        0.0

==========================================================================

 THERMAL CONTRAST (Delta-T)  Target #2 Gunboat  Background #2 Water
View Dir |    MRT Delta T (K)     |    MDT Delta T (K)     | Lock-on Delta-T
 (deg)  |   NFOV        WFOV   |   NFOV        WFOV   |
----------|-------------|-------------|-------------|-------------|--------------
  000        9.7         8.9       42.3        14.4        0.0
  045       10.3         9.6       42.1        14.0        0.0
  090       10.5         9.8       33.0        11.2        0.0
  135       10.5         9.8       24.4         7.8        0.0
  180       10.4         9.6        7.2         7.2        0.0
  225       10.4         9.8       22.9         8.8        0.0
  270       10.6         9.9       31.0        10.6        0.0
  315       10.2         9.6       42.1        13.7        0.0

==========================================================================

 TEMPERATURES (K)    Target #2 Gunboat  Background #2 Water
View Dir | Bkgd Temp | MRT Temperature (K) | MDT Temperature (K) | Lock-on Temp
 (deg)  |   (K)    |  NFOV     WFOV    |  NFOV      WFOV    |    (K)
----------|-----------|----------|----------|----------|----------|--------------
  000  269.2   279.2        279.3      316.3       289.2        300.0
  045    0.0   279.5        279.5      316.3       289.3        300.0
  090    0.0   279.7        279.7      308.6       288.1        300.0
  135    0.0   279.7        279.7      302.3       284.8        300.0
  180    0.0   280.0        279.9      284.2       284.2        300.0
  225    0.0   279.7        279.6      300.9       287.7        300.0
  270    0.0   279.8        279.8      306.6       287.6        300.0
  315    0.0   279.5        279.5      316.3       289.0        300.0

==========================================================================
 RANGES         Target #2 Gunboat  Background #3 Water
View Dir | MRT Detection Range (kft) | MDT Detection Range (kft) | Lock-on Range
 (deg)  |   NFOV          WFOV   |   NFOV          WFOV    |     (kft)
----------|-------------|-------------|-------------|-------------|---------------
 000       99.3        75.9       29.8        24.2        0.0
 045      112.8        88.8       27.9        22.4        0.0
 090      114.0        88.8       20.5        16.2        0.0
 135      112.8        88.8       12.5        16.2        0.0
 180      100.5        77.7       15.6        15.6        0.0
 225      112.8        88.8       11.9        10.1        0.0
 270      114.7        88.8       20.5        16.2        0.0
 315      112.8        88.8       27.9        22.4        0.0

==============================================================================

 THERMAL CONTRAST (Delta-T)  Target #2 Gunboat  Background #3 Water
View Dir |     MRT Delta T (K)     |     MDT Delta T (K)      | Lock-on Delta-T
 (deg)  |   NFOV          WFOV   |   NFOV          WFOV    |
----------|-------------|-------------|-------------|-------------|---------------
 000       9.6        8.8      42.2        14.3        0.0
 045      10.2        9.5      42.0        13.9        0.0
 090      10.4        9.7      32.8        11.0        0.0
 135      10.4        9.7      24.3         7.7        0.0
 180      10.4        9.5       7.1         7.1        0.0
 225      10.3        9.7      22.8         8.6        0.0
 270      10.5        9.8      30.9        10.5        0.0
 315      10.1        9.5      42.0        13.5        0.0

==============================================================================

 TEMPERATURES (K)    Target #2 Gunboat  Background #3 Water
View Dir | Bkgd Temp | MRT Temperature (K) | MDT Temperature (K) | Lock-on Temp
 (deg)  |   (K)    |  NFOV     WFOV    |  NFOV      WFOV    |    (K)
----------|-----------|----------|----------|----------|----------|--------------
 000  269.3    279.2        279.3     316.3       289.2       300.0
 045   0.0     279.5        279.5     316.3       289.3       300.0
 090   0.0     279.7        279.7     308.6       288.1       300.0
 135   0.0     279.7        279.7     302.3       284.8       300.0
 180   0.0     280.0        279.9     284.2       284.2       300.0
 225   0.0     279.7        279.6     300.9       287.7       300.0
 270   0.0     279.8        279.8     306.6       287.6       300.0
 315   0.0     279.5        279.5     316.3       289.0       300.0

                   0.0 -> No Value Computed.
                  -1.0 -> No Solution Possible.
                  -2.0 -> Sensor is Above Overcast.
```

Target Data Entry Form

Target Name

The target defines the size and physical characteristics used in the EOTDA.

To Use: Press button to the right of Target ID name. Select the desired target.

Target Heading

Target heading refers to the direction of the target front with respect to north. The geometry of the target heading and view direction affects a) the perceptible illumination on target (TV), b) the perceptible solar heating on target (IR), and c) the perceptible target size (TV and IR).

To Use: Select Target Heading by using the slider bars, or you can directly edit the number in the text boxes. Enter 270 for a target that faces west.

Target Position (TV only)

Target position is with respect to the sloped background (on the slope or at the base of the slope). Only the TV model uses this parameter. The position of the target affects a) the amount of diffuse and reflected illumination on the target and b) the ability of the sensor to see the target.

To Use: Select Position on Slope (TV only). Press button to the right of position. Select the desired position.

Target Operating State

Operating state is the condition of the target at Time Over Target. Operating state is used only in the IR model. An 'off' target is heated by the environment only. The engine and exhaust system contribute to the heating of an 'idle' or hovering target. The wheels or tractor treads will be heated on an 'exercised' target.

To Use: Press button to the right of operating state. Select the desired operating state.

Target Speed

Speed is the velocity of a mobile target. The speed of the target is used in the IR model only. The movement of the target and the wind speed have a cooling effect on the target.

To Use: Select Speed by using the slider bars, or you can directly edit the number in the text boxes.

Target Elevation (IR only)

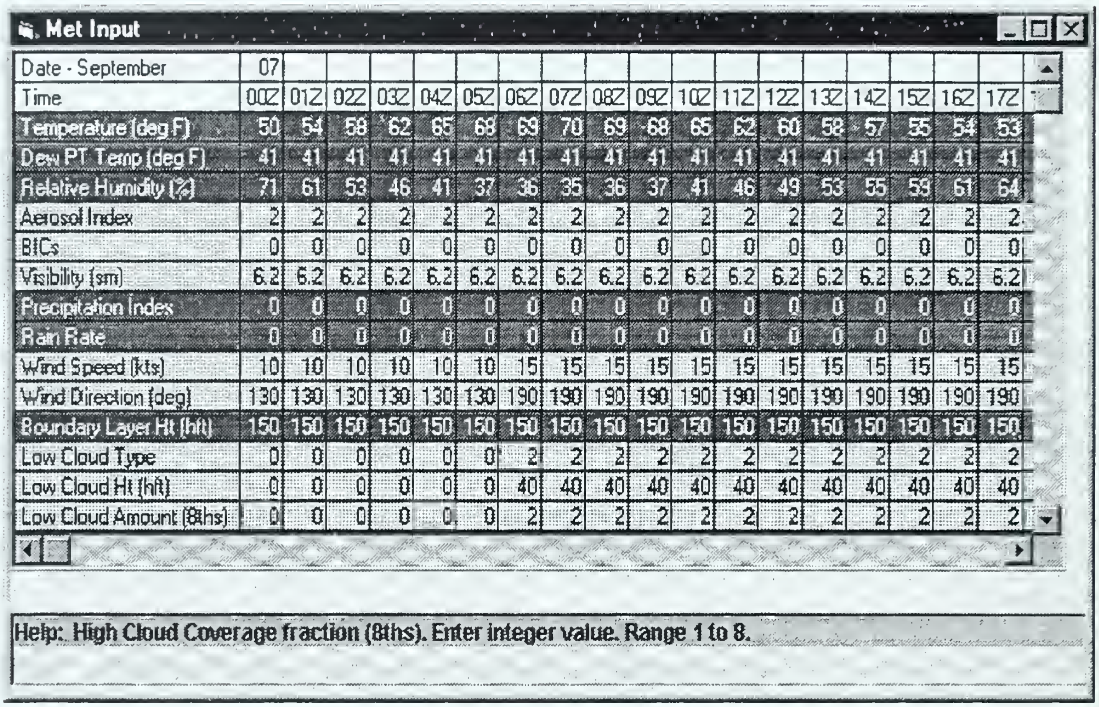
Elevation is the height of the target area above sea level. Elevation is used to compensate for the increased insolation with height. This feature is used only in the IR model and there is no effect below 2000 feet.

To Use: Enter a number between 0 and 12,000 ft in the test box or use the arrows to increment or decrement the value in the text box. The target elevation does not appear when the Target Data Entry Form is called by double-clicking on a Target picture.

Figure C.2 Target Data Entry Form (Descriptive)

Meteorological Data Input Form (24 hours)

(Graphic and Descriptive Explanations)



Date - September	07																	
Time	00Z	01Z	02Z	03Z	04Z	05Z	06Z	07Z	08Z	09Z	10Z	11Z	12Z	13Z	14Z	15Z	16Z	17Z
Temperature (deg F)	50	54	58	62	65	68	69	70	69	68	65	62	60	58	57	55	54	53
Dew PT Temp (deg F)	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Relative Humidity (%)	71	61	53	46	41	37	36	35	36	37	41	46	49	53	55	59	61	64
Aerosol Index	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
BICs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Visibility (sm)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Precipitation Index	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rain Rate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind Speed (kts)	10	10	10	10	10	10	15	15	15	15	15	15	15	15	15	15	15	15
Wind Direction (deg)	130	130	130	130	130	130	190	190	190	190	190	190	190	190	190	190	190	190
Boundary Layer Ht (hft)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Low Cloud Type	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2
Low Cloud Ht (hft)	0	0	0	0	0	0	40	40	40	40	40	40	40	40	40	40	40	40
Low Cloud Amount (8ths)	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2

Help: High Cloud Coverage fraction (8ths). Enter integer value. Range 1 to 8.

Figure C.3 Meteorological Data Input Form

Met Input Screen Parameters

The Met input requires hourly data of the following weather parameters at the target site: surface temperature, surface dew point temperature, the aerosol, Battlefield Induced Contaminants (yes or no), visibility, precipitation index, rain rate, wind speed and direction, boundary layer height, low, middle and high cloud data (type, height, and amount).

SURFACE AIR TEMPERATURE

Range: -40 to 122 deg F
The temperature and dewpoint are used primarily to compute the relative humidity. Relative humidity, along with aerosol and visibility are used to compute an extinction coefficient. Extinction coefficient is used in IR, TV, and Laser models.

SURFACE DEWPOINT TEMPERATURE

Range: -40 to 122 deg F The Dewpoint temperature cannot exceed the Surface Temperature. The temperature and dewpoint are used primarily to compute the relative humidity Relative humidity, along with aerosol and visibility are used to compute an extinction coefficient. Extinction coefficient is used in IR, TV, and Laser models.

AEROSOL INDEX

Aerosol Index refers to the dominant atmospheric particulate in the boundary layer. The definition includes camouflage smokes.
Aerosol model along with relative humidity (temperature and dewpoint) and visibility is used to compute an extinction coefficient. As the extinction coefficient gets larger, the signal at the sensor gets smaller.
Tropospheric aerosol has the lowest extinction and maritime has the highest. Desert aerosols are independent of relative humidity. Navy maritime aerosols are defined by air mass history and wind speed. Aerosol is used in IR, TV, and Laser models.

Range: 1-17.
1 = Rural
2 = Urban
3 = Maritime
4 = Tropospheric
5 = Desert
6 = Navy Maritime Open Ocean (NMOO) Light Antecedent Winds (0-10 kts)
7 = NMOO Moderate (11-20 kts)
8 = NMOO Strong (>20 kts)
9 = Navy Maritime Intermediate Conditions (NMIC) Light Antecedent Winds (0-10 kts)
10 = NMIC Moderate (11-20 kts)
11 = NMIC Strong (>20 kts)
12 = Navy Maritime Strong Continental Conditions (NMSCC) Light Antecedent Winds (0-10 kts)
13 = NMSCC Moderate (11-20 kts)
14 = NMSCC Strong (> 20 kts)
15 = White Phosphorous Smoke
16 = Fog Oil
17 = Hexachloroethane
98 = Advection Fog
99 = Radiation Fog

BATTLEFIELD INDUCED CONTAMINANTS

Range: 0 = None, 1 = BIC are present.

Battlefield Induced Contaminants (BIC) are the persistent pall of smoke and dust that sometimes covers areas where intense combat has occurred When BIC is observed, the user's aerosol selection should be from among the aerosol choices OTHER than smoke (i.e., the user should chose the aerosol appropriate to the prevailing air mass), so the BIC and air mass degradation effects can be combined.

VISIBILITY

Range: 0.1 to 60.0 miles.

The visibility is a very important parameter in the EOTDA's calculation of extinction coefficient.

PRECIPITATION INDEX

Range: 0 = None, 1 = Rain, 2 = Snow

Precipitation Index refers to the type of precipitation present.

RAIN RATE

Range: 0= None, 1= Drizzle (.01 in/hr), 2 = Light(.05 in/hr), 3 = Moderate - Heavy (.10 in/hr).

WIND SPEED

Range: 0 to 99 knots

Only the IR EOTDA uses wind data.

WIND DIRECTION

Range: 0 to 359

Surface wind direction in degrees as measured from True North.

Only the IR EOTDA uses wind data.

BOUNDARY LAYER

Range: 1 to 400 hundred feet (hft)

The boundary layer is the height of the inversion and defines the division of the two layer model used by the EOTDA. An extinction coefficient is computed for each layer. The extinction coefficients are used to compute the effect on incoming radiation and the efficiency of signal transmission from the target scene to the sensor. If the sensor is above the boundary layer, the model uses a weighted average for signal transmission. The boundary layer is used in the IR, TV, and Laser models.

CLOUDS

Although it is standard procedure to report only observable clouds, the EOTDA can be sensitive to clouds above an overcast. Therefore, you are encouraged to provide additional cloud data above an overcast.

CLOUD TYPE

Ranges:

Low Clouds - 0 = None, 1 = Stratus or StratoCumulus, 2 = Cumulus or Cumulonimbus.
Middle Clouds - 0 = None, 3 = Altostratus, Altocumulus, 4 = Nimbostratus
High Clouds - 0 = None, 5 = Thick Cirrus, 6 = Thin Cirrus

The EOTDA models require cloud type in order to compute extinction.

CLOUD HEIGHT

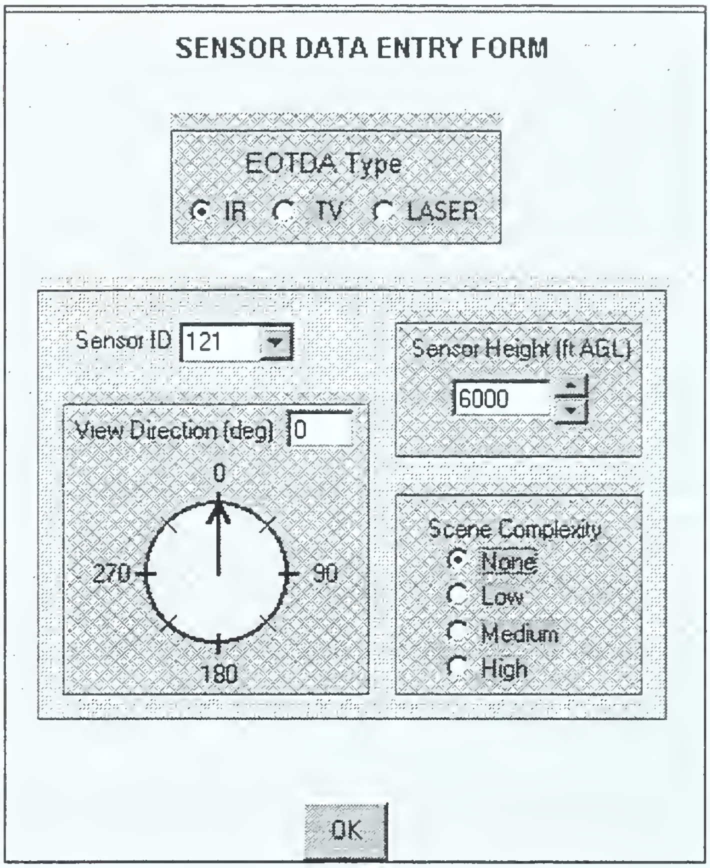
Range: 0 to 400 hundred feet (hft).

Cloud base height is reported in hundreds of feet. Mid cloud height must be greater than low cloud height. High cloud height must be greater than low and middle cloud heights.

CLOUD AMOUNT

Range: 1 to 8

Sensor Data Entry Form
(Graphic and Descriptive Explanation)



EOTDA Type: ● IR ○ TV ○ LASER

Sensor ID: 121

Sensor Height (ft AGL): 6000

View Direction (deg): 0

Scene Complexity: ● None ○ Low ○ Medium ○ High

Figure C.4 WinEOTDA Sensor Data Entry Form

Sensor Data Entry Form

EOTDA Type

EOTDA Type defines the EOTDA model that will be executed. The EOTDA supports three sensor types (IR, TV, or Laser). Required sensor entries for the IR and TV differ from the Laser. Execution time and output products vary among sensor types.

To Use: Press radio button to make your selection.

IR or TV Sensor ID

Sensor ID is the corresponding number for each sensor. The list of software-supplied sensors and IDs is in a CONFIDENTIAL appendix of the User's Manual. When the sensor ID is matched with the sensor name, it is the responsibility of the user to follow the necessary security procedures. If you have an IR sensor type, a simplified (austere) EOTDA is available by selecting 'Trans only' for Sensor ID. The output is reduced to IR Visibility, Transmissivity, and Absolute Humidity.

To Use: Press button to the right of Sensor ID number. Select the desired sensor.

Sensor Height

Sensor height is the vertical distance of the sensor above the surface. If your operation involves a pop-up maneuver, choose a height that best represents anticipated detection of target. The distance to the horizon is a function of sensor height. Lock-on and detection ranges are limited by this distance.

To Use: Enter a number between 100 and 40,000 ft in the text box or use the arrows to increment or decrement the value in the text box.

View Direction

The sensor view direction is described in degrees clockwise with respect to true north. The geometry of the view direction and the target heading affects a) perceptible illumination on target (TV), b) perceptible solar heating on target (IR), and c) perceptible target size (TV and IR). If the sensor is facing forward on a westbound plane, enter 270.

To Use: Enter a number between 0 and 359 in the text box or click on the Dial with the mouse.

Left mouse click on the Dial - the value in the text box will be rounded off to the nearest multiple of 15 degrees. Right mouse click on the Dial - the value in the text box will be the exact number.

To change the value in the text box by one, left mouse click on the View Direction label; conversely, right mouse click on the View Direction label will decrease the value in the text box by one.

IR Complexity

IR scene complexity characterizes the 'busyness' of the target area. Complexity describes the number of objects or patterns in the immediate target vicinity that can be mistaken for the target. Judgments of scene complexity must be based on the structure in the scene and must not be influenced by the magnitude of the contrast between scene features. See User's manual for examples of four levels of scene complexity. The ability to distinguish a target among other objects in a scene depends upon both the scene complexity and the scene thermal contrast. Complexity is used in computing MRT detection range for all sensors.

To Use: Press radio button to make your selection.

TV Clutter

TV clutter level describes the 'busyness' of the target area, including both the number of objects comparable in size and shape to the target and the magnitude of the contrast between scene features. Judgments of clutter level must take both of these factors into consideration.

To Use: Press radio button to make your selection.

Laser System Mode

Mode refers to the arrangement of laser components (designator/receiver/ranger). Mode 1: Compute maximum lock-on receiver range. Mode 2: Compute maximum designator range. Mode 3: Compute maximum range for colocated designator and lock-on receiver. Mode 4: Compute maximum designator/ranger range. Mode 5: Compute maximum lock-on receiver/ranger range. Mode 6: Compute maximum range for colocated designator and lock-on receiver. Mode 7: Compute ranging range only.

To Use: Press radio button to make your selection.

Laser Receiver/Designator/Ranger ID

ID is the corresponding number for each system component. The list of software-supplied sensors and IDs is in a CONFIDENTIAL appendix of the User's Manual. When the sensor ID is matched with the sensor name, it is the responsibility of the user to follow the necessary security procedures. The Laser EOTDA does Not support ground designators.

To Use: Press button to the right of Sensor ID number. Select the desired sensor.

Laser System Heights

System height is the vertical distance of the sensor above the surface. If your operation involves a pop-up maneuver, choose a height that best represents anticipated detection of target. The distance to the horizon is a function of sensor height. Lock-on, detection, and ranging ranges are limited by this distance.

To Use: Enter a number between 100 and 40,000 ft in the test box or use the arrows to increment or decrement the value in the text box.

Laser Ranges

The ranges required for input are the slant path distances between the target and system. Ranges are limited by the distance to horizon. The Laser model uses a fixed distance to target for one element of the system (designator/receiver/ranger) to compute the corresponding range.

To Use: Enter a number between 1600 and 164,000 ft in the test box or use the arrows to increment or decrement the value in the text box.

WinEOTDA Graphical Output

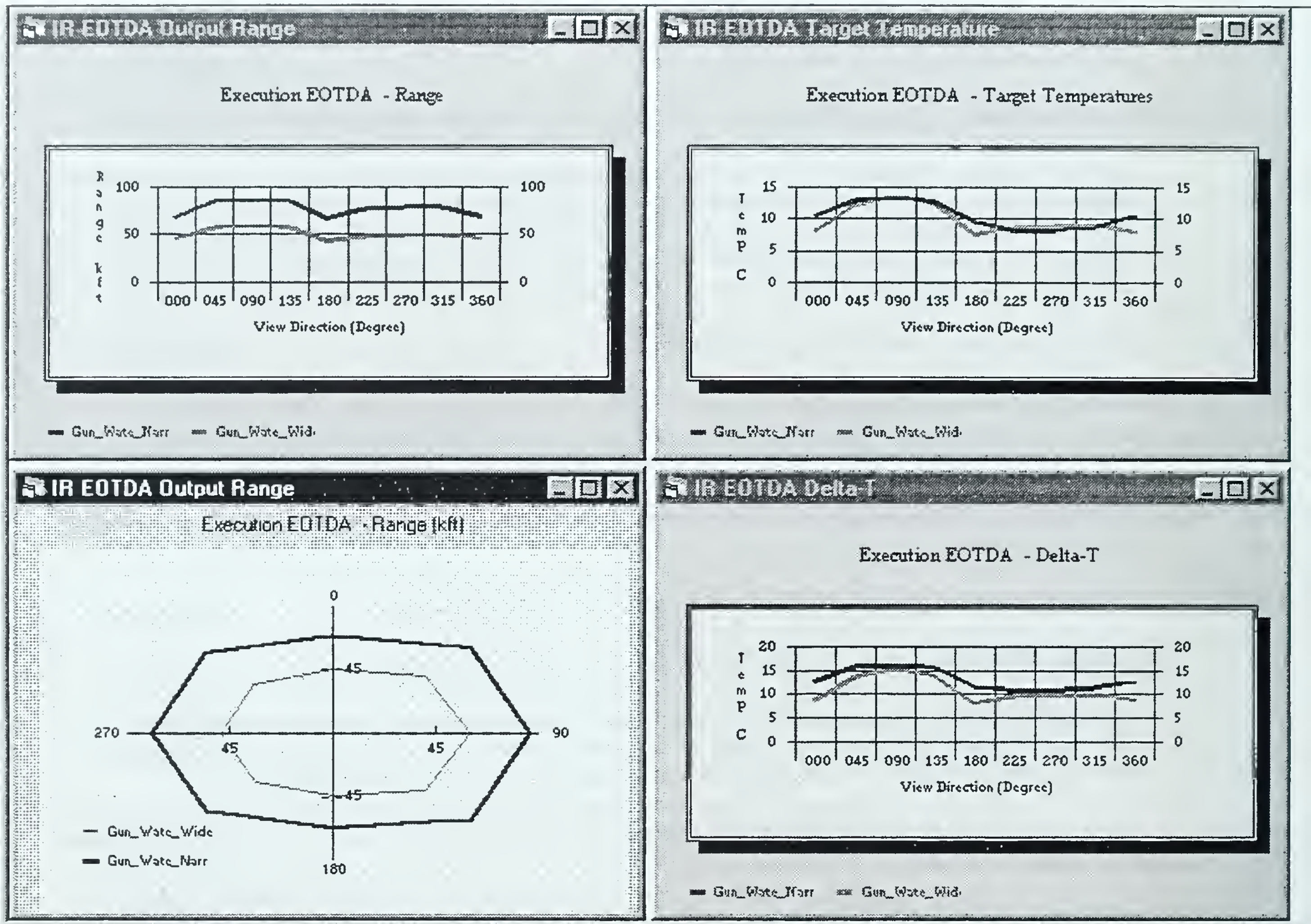


Figure C.5 WinEOTDA Graphical Output
Sample using Sensor 115 from look-up table

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